NGST Cost and Process IPT

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GSFC Office of Space Science Programs

Next Generation Space Telescope

Where does NGST stand today?

- Current cost estimate driven by resource cap
  - Pre-Phase A to Phase B => $230 M (96$)
  - Phase C/D with a 2003 start => $500 M (96$)
  - Launch in 2007 and 10 years of Operations => $400 M (96$)
- The challenge: To develop a World-Class Observatory under a $500 M (96$) cap
- What other missions cost:

Comparable Missions	Development (Phase C/D) Cost (RY$)
– HST	$ 1,545 M
– AXAF	$ 1,450 M
– CGRO	$ 557 M
– SIRTF	$ 433 M

Cost & Process IPT Charter

- To Identify practical cost control strategies for the NGST program and establish <u>cost credibility</u>.

- To treat cost as an <u>integral factor</u> to NGST management and design.

- To work closely with "<u>consumers</u>" of cost estimates
  - NGST project management
  - Agency independent reviewers

Cost & Process IPT
Tasks

- Bound the Problem - to understand the challenge and charter.
- Benchmark *relevant* programs - to identify and understand effective cost reduction and containment approaches.
- Formulate Solutions - supported by cost/benefit analyses, that the NGST project can adopt.

Cost & Process IPT
Primary Tasks

- **Bound the Problem**
  - Understand the scope of the challenge
    - What do the current cost estimating relationships predict for NGST
    - What are the cost-driving parameters
    - What are the critical cost cliffs for NGST technologies and processes
  - Identify the critical assumptions per range of cost estimates
  - Survey the customer base to understand the attributes of credible and non-credible cost estimates
    - Internal and external to NASA

Cost & Process IPT
Primary Tasks

- **Benchmarking Activities**
  - **Study relevant projects for successful and unsuccessful cost control approaches**
    - **Project management structure**
    - **Project procurement process and fee structure**
    - **Degree of government participation and oversight**
    - **Degree of international involvement**
    - **Root causes of cost uncertainty and overrun**
  - **Benchmarking candidates:**
    - **Great Observatories: HST, AXAF, GRO, SIRTF**
    - **Peer Program: SIM**
    - **External to NASA: Boeing 777, DoD/AF/NRO, other**
  - **Identify strategies and management practices for those projects that have achieved high results at low cost; assess application to NGST**
    - **Internal and external to NASA**

Cost & Process IPT
Primary Tasks

- **Formulate Solutions**
  - **Recommend cost reduction and control initiatives for adoption by NGST**
    - **For promising, but new and untried approaches, develop plans for validation**
    - **Possible validation through NEXUS flight demonstration (scheduled for 2003)**
  - **Outline a roadmap for implementing recommended cost reduction and containment initiatives**
    - **Appropriate evolution of management structure**
    - **Appropriate procurement vehicles, and associated fee structure for different phases and activities**
    - **Nature and degree of government participation and oversight**
    - **Mode of working with international partners**
    - **Lessons-learned for all non-technology factors**

Cost & Process IPT Products

- **IPT Study Report**
  - **A chronicle and summary of the IPT's work**
  - **Proper documentation will allow others to benefit from benchmarking activities**
- **Cost Reduction and Control Roadmap**
- **Reviews**
  - **Report periodically at NGST quarterly reviews**
  - **Report periodically at NGST SRBs**
  - **Report to independent assessment teams**

Cost & Process IPT Membership

- **Co-Leads:**
  - Paul Geithner, GSFC, NGST Systems Engineer
  - Lisa Guerra, GSFC, Program Integration Manager
- **Core Team:**
  - Committed to accomplishing the task
  - Approximately 8 people, at GSFC for meeting convenience
  - Range of disciplines included to address wide scope of issues: science, technology development/mission studies, systems development, cost estimation, procurement, operations
- **Extended Team:**
  - Executes specific tasks and provides support at direction of core team
  - Tap resources at other Centers and Headquarters as appropriate
  - Solicit input and feedback from contractor community (TRW, Ball, L-M, etc.)

Cost & Process IPT Schedule

- Period of performance is during Pre-Phase A
  - Products required by December 1998
    - Time for incorporation into Project material prior to Spring ‘99 reviews and “Phase A” system contract awards
  - 1 year for Cost and Process IPT to produce
- Immediate agenda for January
  - Establish core team membership
  - Identify selection criteria and projects for case study
  - Determine most effective ways to benchmark
  - Outline detailed schedule for entire year
  - Identify initial assignments (reading material, research, etc.)
  - Determine whether Continuous Process Improvement (CPI) Bootcamp is necessary

Integrated Science Instruments Module (ISIM)

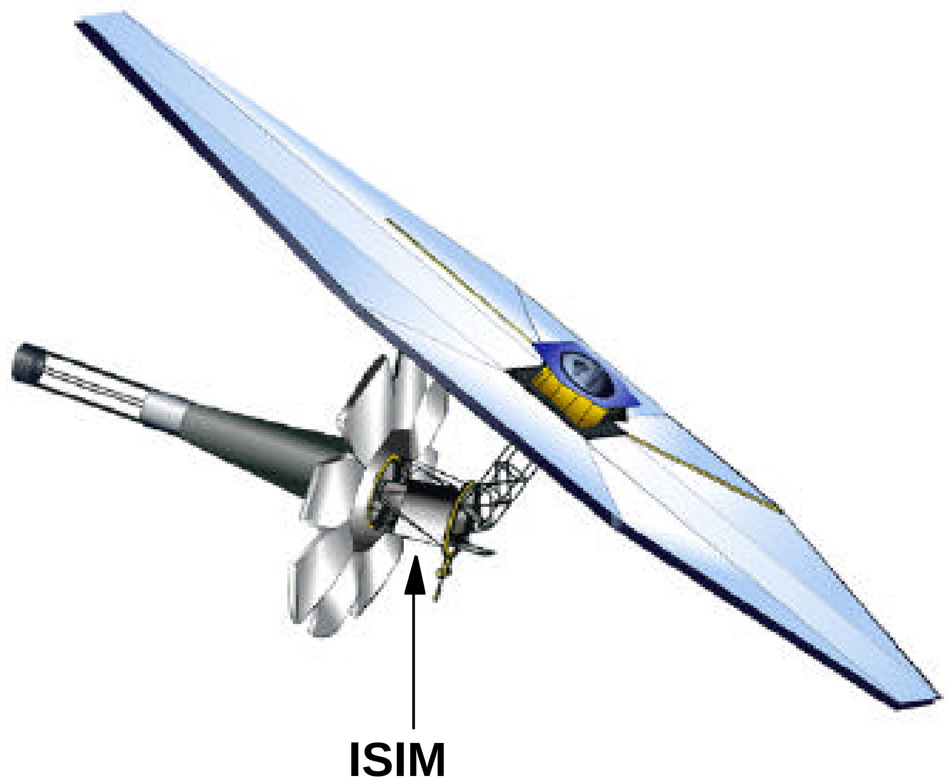
R. Burg

Astronomer/Systems Engineering Group

Johns Hopkins University

An Optimized ISIM is the *most cost effective way to maximize the science return*

- **Trade studies have taught us that investing in the science instruments gives large payoffs - *large FOV optical design, low noise detectors, low temperature operation***
- **ISIM returns are potentially so large that three studies (external, industry systems and internal) are planned**



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External ISIM studies will provide *innovative instrument* concepts to the NGST project

- **External *NRA* solicited to university, industrial and government research centers**
  - **Will enlarge our expectations - We expect to receive proposals for "Cutting Edge" instrumentation**
  - **Involves large community of instrument makers in the NGST program**
  - **An opportunity for non-traditional teaming relations to form**
  - **Nominally five proposals will be accepted - each will be funded at the ~$150k level and studies will start in March**

Internal ISIM study will give the project *the confidence that the ISIM will perform as needed for the planned cost*

- Government-led ISIM *Yardstick* study is charged with:
  - ***Providing a guiding design that is fully engineered***;
    - a "minimal" NGST instrument suite that meets DRM requirements - sets the bar high!
    - aggressively designed but a guarantee of feasibility
    - and with emphasis on expanding the work already done
  - ***Establishing technical feasibility to***
    - uncover problems and system incompatibilities
    - demonstrate that the design is robust, particularly the thermal
  - ***Fully costing the ISIM to establish bottom line credibilility***
    - full bottom up analysis of fully engineered design
    - how important will the integrated approach be to success
- Team being formed now - 9 month study planned
  - Mark Matsumura (instrument manager), P. Bely (team leader), Matt Greenhouse, J.Mather, P. Stockman, R. Burg
- Industry systems studies are progressing but are at an early stage
  - BALL contributed to Government Yardstickduring the CAN process; TRW concept on separate VG

The Yardstick ISIM design *simplifies the overall architecture and utilizes the full potential of the 8-m cold NGST*

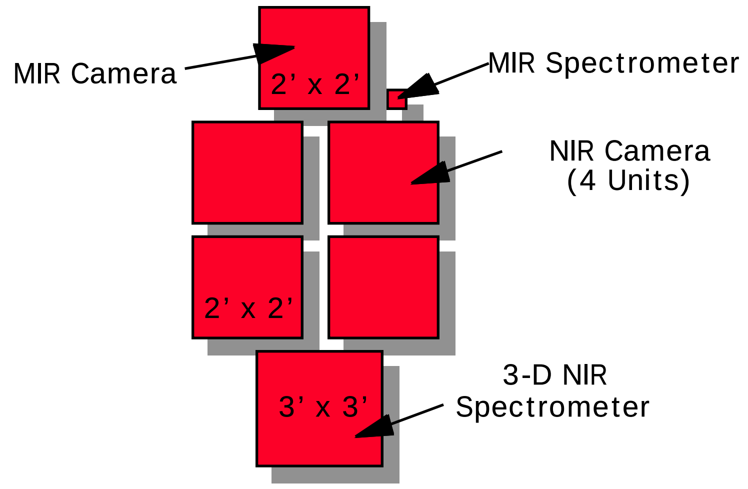
- Design Philosophy
  - Requirements flow from strawman observing plan: large field, large wavelenth coverage, high throughput, imaging and spectroscopy, and parallel modes
    - The *yardstick* ISIM consists of three instruments
      - Near Infrared Camera (NIRCAM) (0.6-5 micron)
      - Near Infrared Spectrograph (NIRSPEC) (0.6-5 micron)
      - Thermal Infrared Camera/Spect. (MIRCAM) (5-30μ)
  - Reduce Complexity through high level systems choices
    - Designed in common with OTA - large FOV optical design
    - Instruments share the focal plane - fully parallel modes
    - Integrated design - reduces interfaces, volume & mass
    - All beryllium (optics, mechanisms, bench) - reduce mass and avoid differential expansion problems
    - Fine guidance performed by the NIR camera, one of the science instruments - large FOV simplifies operations
    - Only two types of detectors to cover 0.6-30 micron range
    - Optics and NIR detectors passively cooled

The Yardstick ISIM is made up of *three instruments that carry out four functions*

Main Instrument Characteristics

Instrument	*Detector*	*Wave-length range*	*Resol. element (microns)*	*Resol. element (mas)*	*F/D*	*Array size*	*Field of view (arcmin)*	*Critically sampled (microns)*
NIRCAM	InSb	0.6-5.3	27	29	23.8	8192	4x4	2.27
MIRCAM	Si:As	5-30	27	230	5.5	1024	2x2	9
NIRSPEC	InSb	0.6-5.3	27	100		4096	3x3	
MIRCAM/ Spec Mode	Si:As	5-30	27	230		1024		

Focal Plane Arrangement



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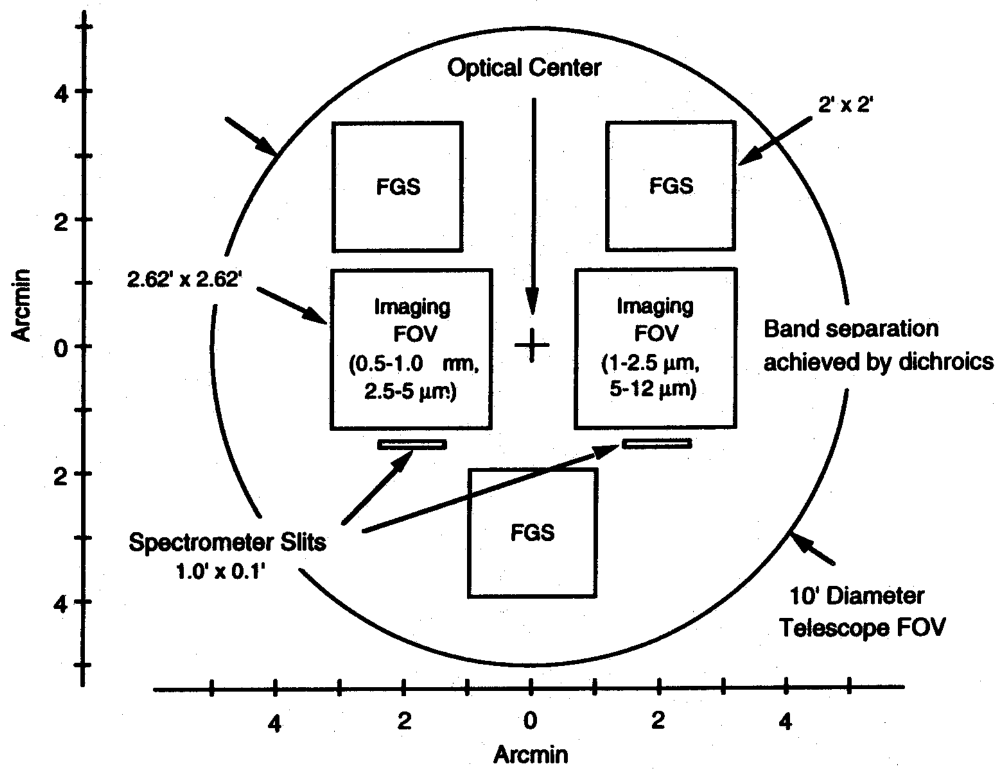
TRW ISIM concept

- 3 Separate guiding cameras
  - Only two are required for guiding - one could be replaced with a 3-d spectrograph
- 4 science cameras view two separate fields - Dichroics used to multiplex in wavelength

Layout of NGST FOV



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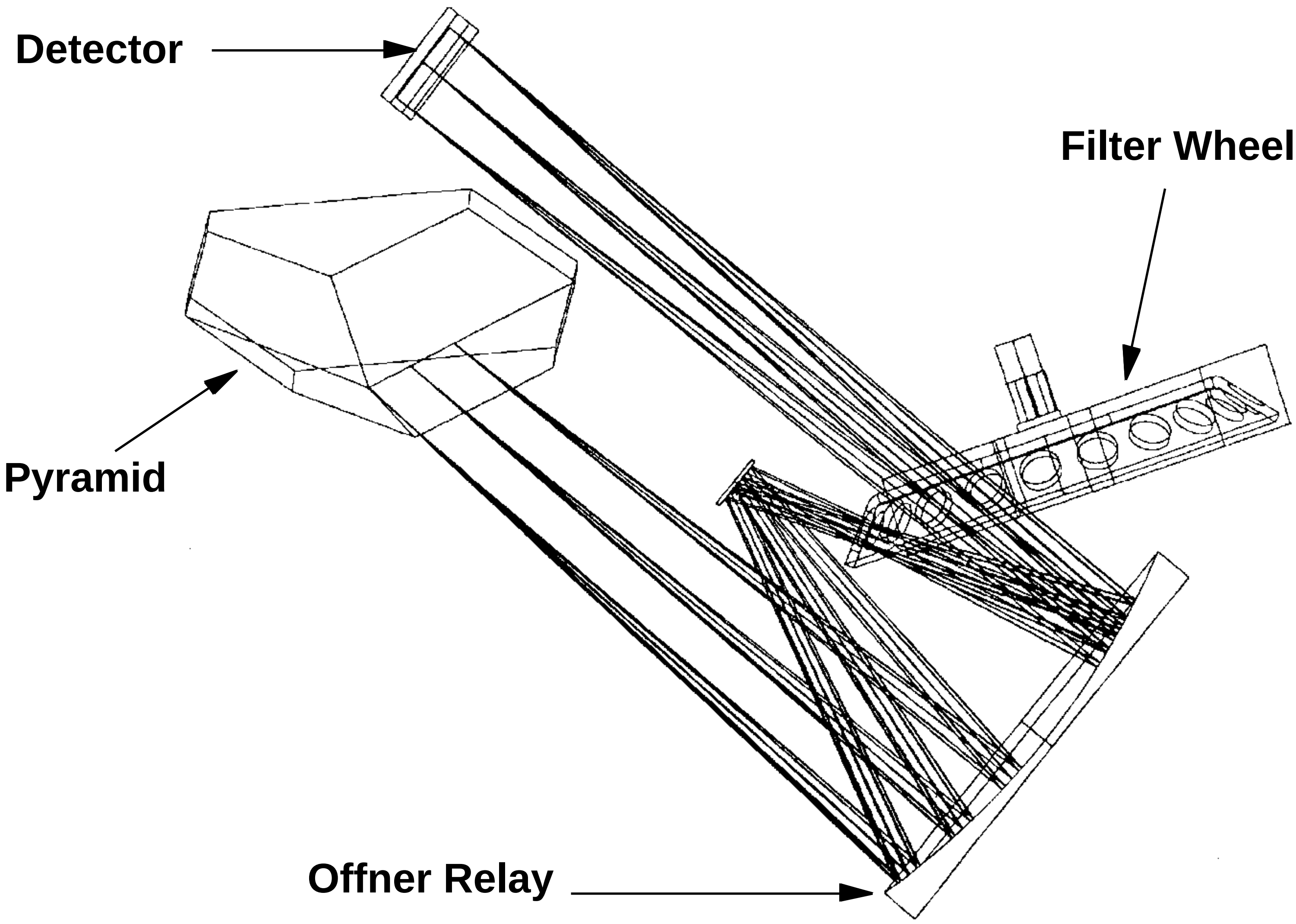
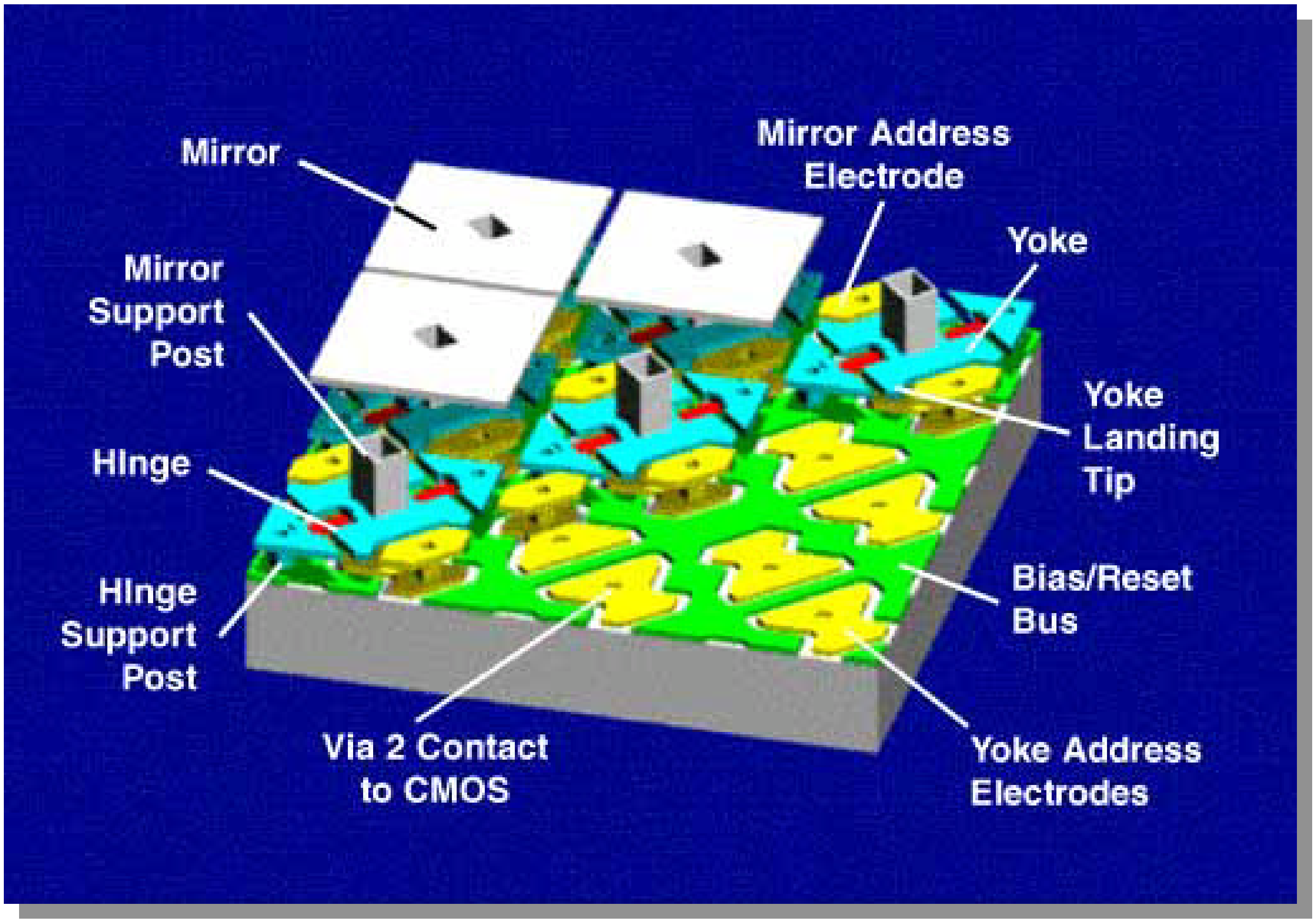
The Wide Field of View of the NGST Yardstick NIR Camera *Maximizes Survey Science, Provides Flexibility for GO programs and Enables the Simple Guiding Sensor architecture*



Yardstick NGST has a *NIR Spectrograph with a 3'X3' FOV*

- Two concepts are being studied
  - Integral Field - Lenslet Arrays (Tigre Spectrograph)
  - Random Access Multiple Slit - Multimirror VLSI
- Novel multislit spectrograph for high survey efficiency



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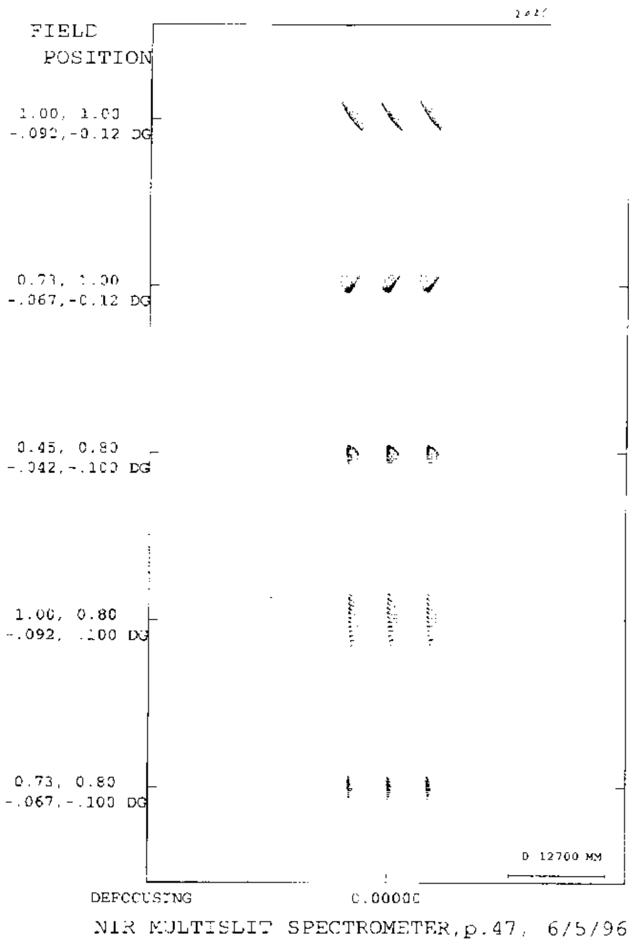
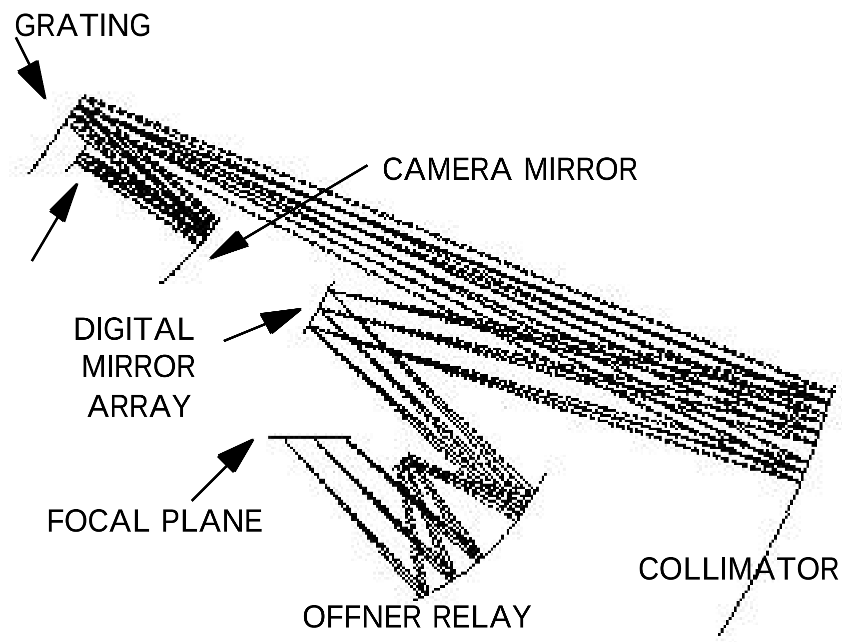
The Yardstick NIR Spectrometer makes full use of the Wide FOV in order to *carry out Redshift Surveys of High-Z Galaxies*





OPTICAL LAYOUT

- High throughput design with two modes of resolution - 200 and 2000

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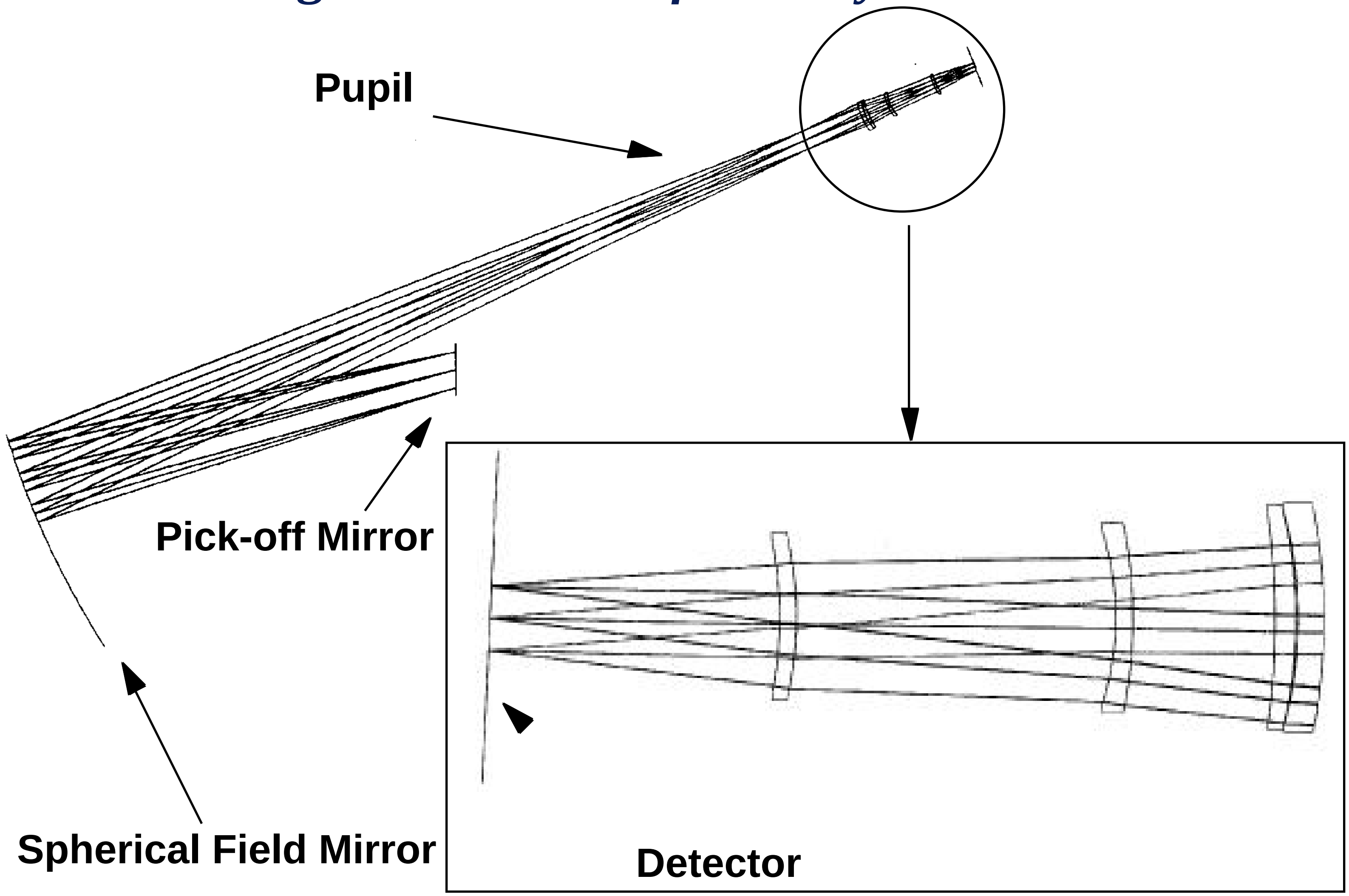
The Yardstick MIRCAM contains both the Spectrometer and the Imager to *maximize flexibility at minimum cost*



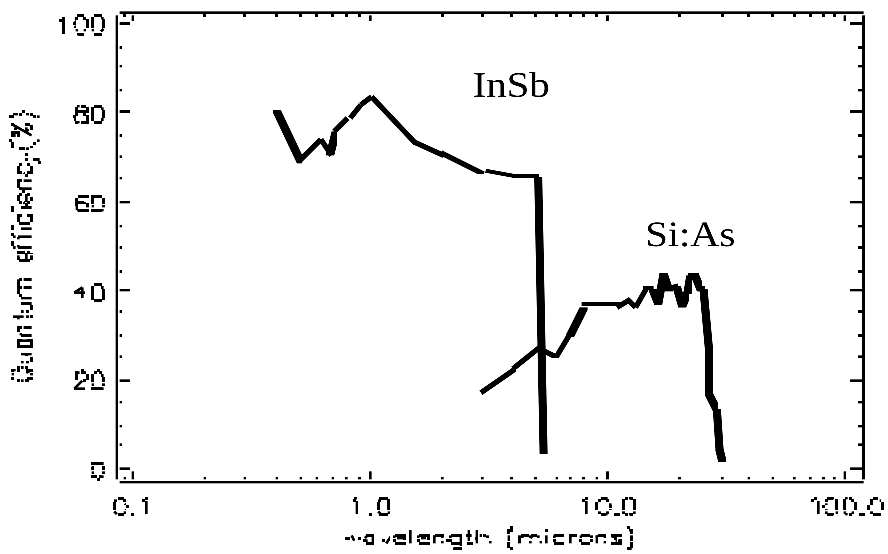
- Slit/Grism/Cross-disperser added for spectrograph mode

NGST Yardstick Detectors *fully cover the Visible-NIR-MIR*

Main characteristics of the detectors

Parameter	*InSb*	*Si:As*
Wavelength coverage (µm)	0.6 to 5.3	5 to 30
Dark current (electrons/s)	0.02*	10
Readout noise (electrons)	15*	30*
Multi-sampled readout noise	4*	8*
Full well	100,000	300,000
Temperature (deg K)	30K	6K
Read out time (µs/pixel)	3	3

*assuming improvement by a factor of 2 to 5 over what is currently available



Typical quantum efficiency of the InSb and Si:As array (courtesy of SBRC)

- **Only Two detector technologies are needed to span Visible-NIR-MIR**

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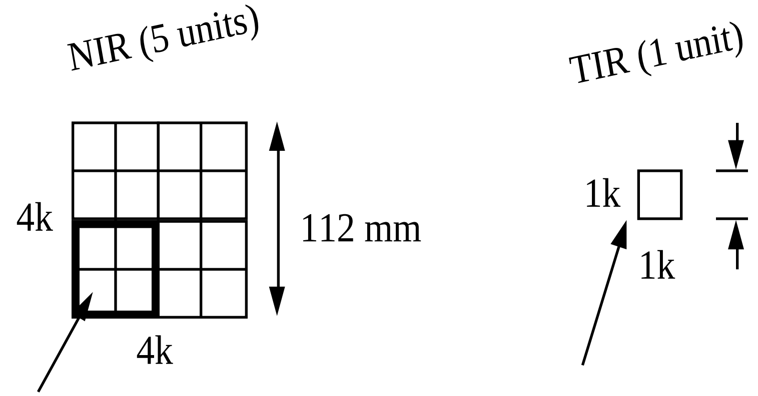
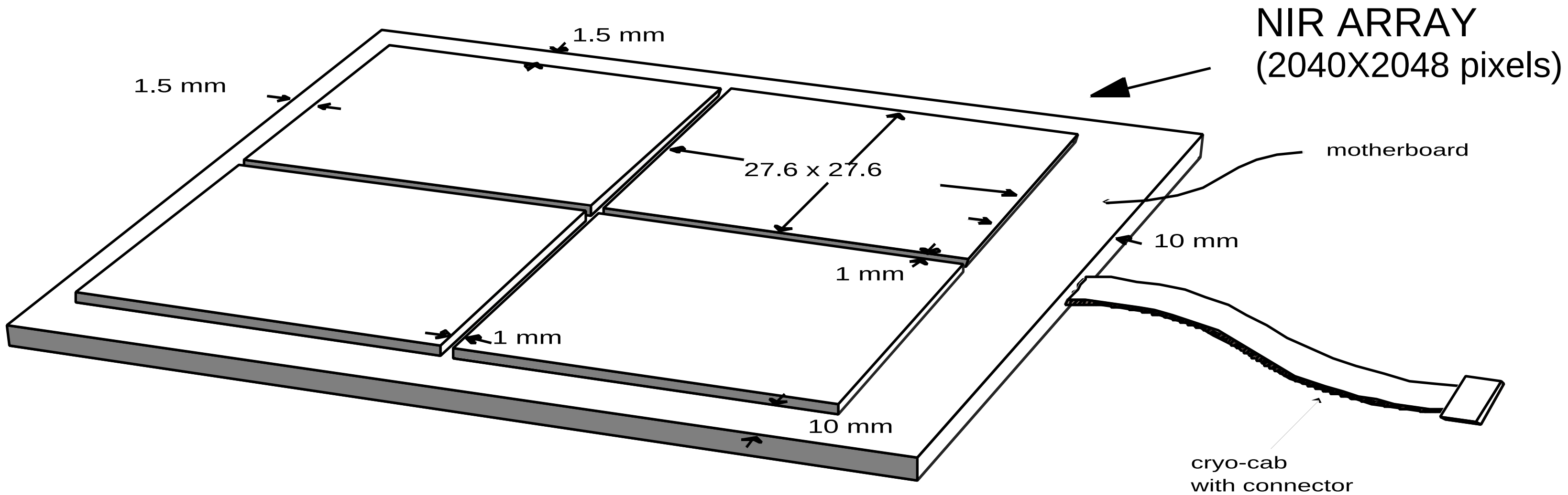
Simple packaging *lowers development costs and reduces risk*



Sixteen 1k x 1k InSb
with 27 micron pixels
arranged in 4 sets of 4

1k x 1k Si:As
with 27 micron pixels



- **One Detector Package for both NIR Spectrograph and Camera, MIR needs separate packaging**

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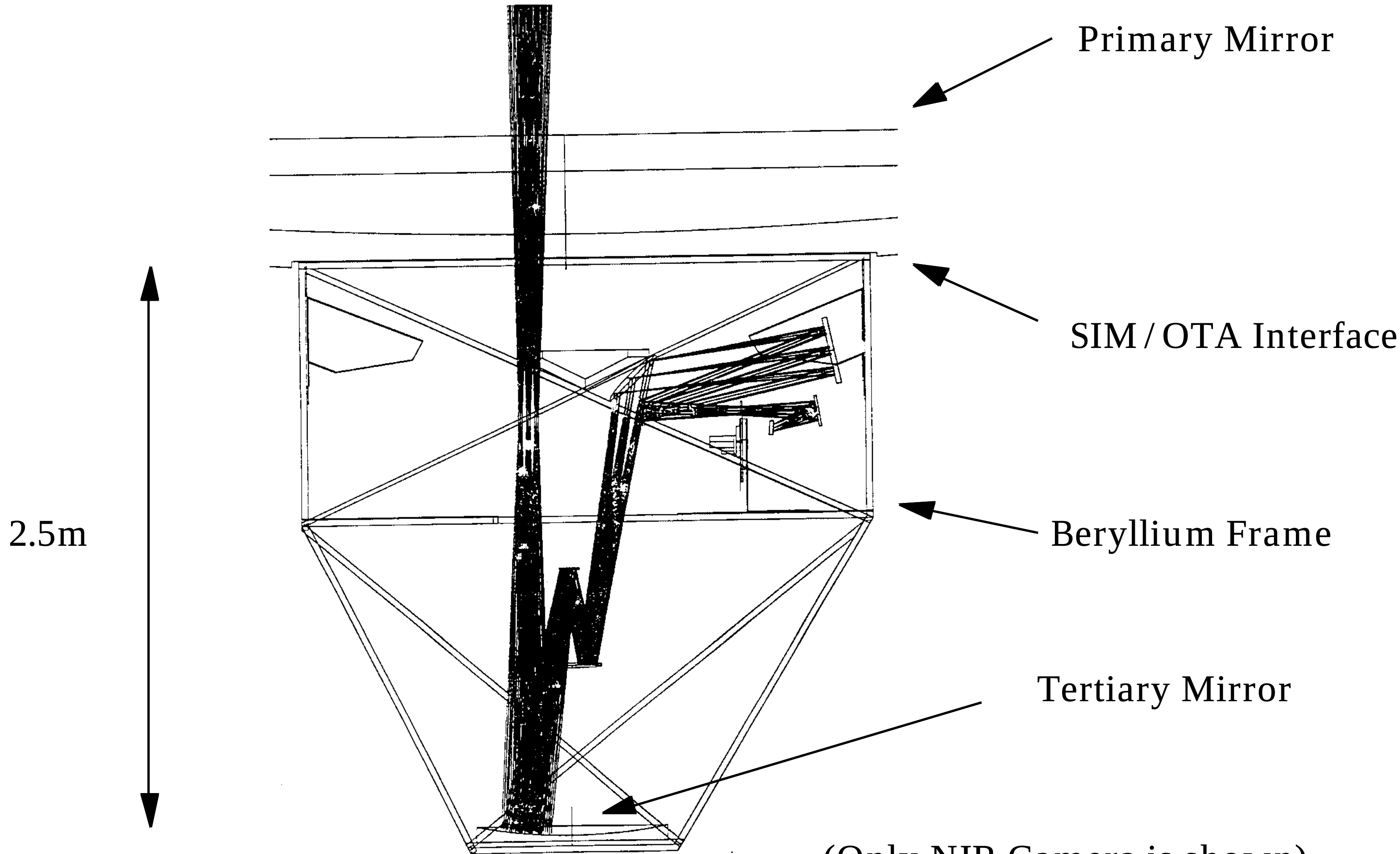
Yardstick Instruments *share a common frame and optical bench*



- **Instruments are not in traditional boxes**
- **Beryllium is baselined to simplify systems engineering: Strength, Stability, Thermal robustness of design**

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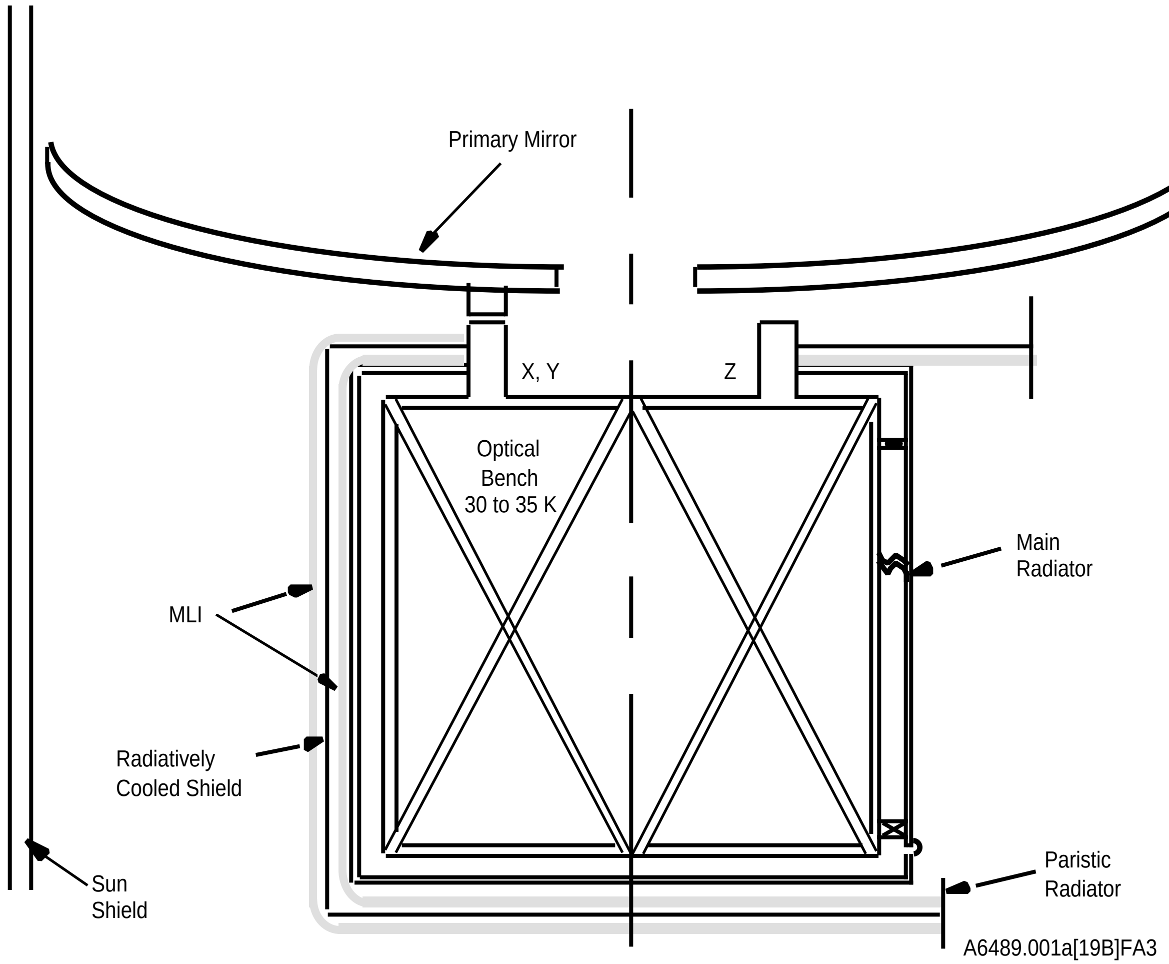
Yardstick uses *passive cooling* which introduces no vibration source and is low in cost

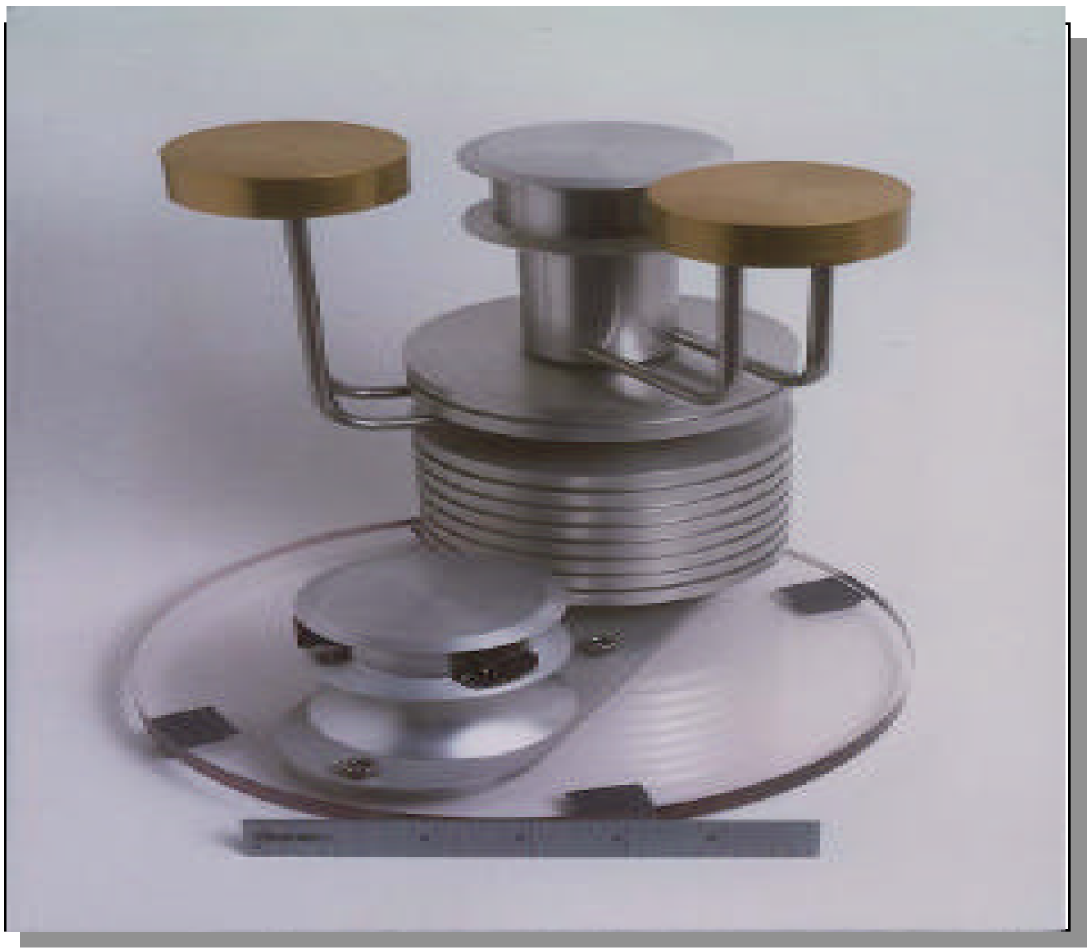


Schematic of the thermal system

- Very important to study this. EOL temperature for InSb can be no warmer than 35K

Yardstick MIR detector (SI:AS) *needs active cooler*

- Brayton-Cycle Compressor Rotor runs at over 30,000 RPM, cooler reaches 6K and does not introduce spurious vibrations
- Sorption cooler is alternative



Brayton-cycle Cooler

Yardstick Design *accounts for calibration in order to simplify operations*

- **Calibration Modes include:**
  - **Flat fielding using sky and a lamp mounted on edge of secondary mirror**
  - **Wavelength calibration of spectrometer done pre-launch**
  - **Dark current measured with blank filter**
  - **Flux calibration made with standard sky sources**

Mimimizing Operations Modes *will lower the overall operations cost*

- Operations Modes include:

  NIR Camera

  - Imaging
  - Bright object exclusion
  - Guiding

  NIR Spectrograph

  - Spectrographic mode
  - Imaging
  - Acquisition peak up
  - Point and shoot spectrographic mode

  MIR Camera/Spectrograph

  - Imaging
  - Peak up
  - Spectrograhpic mode

The Yardstick ISIM should *cost significantly less than comparable HST instrument*

- **Cost Saving Measures will include:**
  - **Integrated optical bench: single kinematic mount, no secondary benches, no secondary enclosures, efficient packaging–(but will require tight schedule control during integration and test).**
  - **Large commonality between instruments (detectors, filter wheels, electronics, flight software)**

Item	*Cost Estimate(from CAN study, 1996 K$)*
System Engineering	5500
Optics	5960
Detectors	28350
Electronics & Power	9200
GSC & Software	4000
Cooling System	1820
Mechanisms	7120
Optics Bench	3825
Enclosure	2095
Integr. Test & Verif	9895
Product Assurance	4570
Management and Fee	5700
Science Team	4520
Direct Cost and Fee	16560
TOTAL	**109115**

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How the ISIM program will be *procured and managed* throughout the program will be a key to the NGST success

- The Big Questions are
  - Who will procure the ISIM?
    - Industrial Prime within phase B proposal
    - Industrial Prime with separate AO during phase B
    - The governement in a "traditional" procurement
    - The government as sub-contractor to the prime
    - the government as sub-contractor and soliciting further partners
    - etc.
  - Will the ISIM be truly an "Integrated" instrument?
    - How do we include our International partners
    - How do we involve Universities and Research Centers
  - How will we guarantee that the Science goals will be met
    - Is the DRM enough to score the contractor
    - What mechanism is in place to enforce the DRM metric
    - Performance based or Fixed priced contracting - they are not the same and management approach to insure programmatic success will need to accommodate contractual mode

Our conclusion to date is that *the Yardstick ISIM is in good shape*

- Mission simulations with the strawman science program have
  - **Allowed us to optimize the science instrument complement within the mission constraints**
  - **Demonstrated that the proposed instruments combined with the large aperture of the telescope form an extremely powerful tool for cosmological research which is fully responsive to the *HST and Beyond Committee* report recommendations**
- **The engineering study so far indicates that the yardstick ISIM is**
  - **Technically feasible with no show stoppers but technology development needed for:**
    - **detectors (reduce read noise and dark current by factor of 4, 4096x4096 packaging)**
    - **micro-mirrors at cryogenic temperatures or alternative designs**
    - **quiet coolers for MIRCAM**
- **Planned internal and external studies will refine these conclusions and illuminate alternate concepts**
- **Prototype instruments and detectors planned for testing on ground telescopes and in space on *NEXUS***

MISSION OPERABILITY

Keith Kalinowski

GSFC 440/730

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MISSION OPERABILITY OUTLINE

- THE PARADIGM FOR NGST
- ROLE OF THE OPERABILITY IPT
- THE SCOPE OF OPERATIONS
- EXCERPTS FROM THE GSFC FEASIBILITY STUDY
- TECHNOLOGY OBJECTIVES FOR NGST OPERATIONS

A PARADIGM FOR NGST OPERATIONS

- ***OPERABILITY*** **IS A SYNONYM FOR, AND A RESULT OF MISSION-LEVEL CONCURRENT ENGINEERING AND REQUIREMENTS ALLOCATION**
- **AS A MISSION DESIGN APPROACH IT:**
  - **INFUSES LIFE-CYCLE CONSIDERATIONS INTO DESIGN TRADES** ***(E.G., COST AND COMPLEXITY OF PROPOSED FUNCTIONALITY, ITS DEVELOPMENT, SYSTEM MAINTENANCE, AND OPERATIONS)***
  - **ENSURES THAT THESE ISSUES ARE FACTORS IN HARDWARE AND MISSION PROFILE DECISIONS**
  - **TARGETS NEW TECHNOLOGIES AND METHODOLOGIES WITH SIGNIFICANT POTENTIAL FOR LIFE-CYCLE COST REDUCTION**

NGST OPERABILITY IPT CHARTER

- PROVIDE OPERATIONS SYSTEMS ENGINEERING EXPERTISE TO ALL ELEMENTS OF NGST
- EVALUATE ALTERNATIVE OPERATIONS MODELS FOR COMPLEXITY, COST, AND EFFECTIVENESS
- CONCEPTUALIZE, EVALUATE AND RECOMMEND CANDIDATE DATA SYSTEM ARCHITECTURES
- PROMOTE COMMONALITY AND PORTABILITY IN THE ELEMENTS OF FLIGHT AND GROUND SYSTEM PROCESSES AND SOFTWARE
- IDENTIFY TECHNOLOGY NEEDS; SUPPORT OR UNDERTAKE KEY DEVELOPMENT EFFORTS; LEVERAGE ADVANCES FROM OTHER PROGRAMS
- PROVIDE TRADE STUDY RESULTS TO THE PARALLEL ARCHITECTURE EFFORTS
- PLAN, IMPLEMENT AND CONDUCT THE *NEXUS* MISSION OPERATION - DEMONSTRATING ADVANCES IN DEVELOPMENT PARADIGMS AND KEY ELEMENTS OF THE PLANNED NGST OPERATIONS MODEL

OPERABILITY IPT ORGANIZATION

NGST Operability IPT Lead
Keith Kalinowski

Operability Architect
Steve Tompkins

FSW Concepts Engineer
Ray Whitley

- FSW Development Methodologies
- Flight Data System Architecture
- Flight Autonomy
- Adaptive Scheduler Development

NEXUS Mission Operations Manager
Jack Leibee

- Implementation Planning
- Requirements Definition
- Mission Support

Operability Systems Engineer
Janice Smith

- Flight/Ground Commonality
- Data Protocols, Formats and Processes
- Communications Alternatives
- Architecture Study Trades

Science Operations Architect
Larry Petro

- AHSWG Liaison
- Observation Planning and Scheduling
- Calibration Systems
- User Support

Ground System Technologies Engineer
Jim Jeletic

- Ground Autonomy
- Data Archive Concepts
- Mission Operations Architecture
- SEA Development

OPERATIONALLY, WHAT DO WE HAVE TO WORK WITH?

- RELATIVE TO THE COMPARABLE HST ERA...
  - 25 YEARS OF EXPERIENCE
  - VASTLY IMPROVED FLIGHT AND GROUND PROCESSORS
  - SUPERIOR PROGRAMMING LANGUAGES
  - SUBSTANTIAL FLIGHT AND GROUND AUTONOMY ENTERPRISES
  - CANDIDATE ORBITS OPERATIONALLY SIMPLER THAN LOW EARTH ORBIT
  - AND, MOST IMPORTANTLY: AN EARLY FOCUS ON MISSION LIFE-CYCLE AND A MANDATE TO "DESIGN TO OPERATE"

NGST OPERATIONS SCOPE

Integrated Operations Environment

OTA Operations
- Mirror alignment and initial figure adjustment
- Management of image quality

Instrument Operations
- Guide star and target acquisition
- Readout processing, data compression, and storage
- Instrument monitoring

Spacecraft Operations
- Telemetry monitoring
- Attitude determination
- Constraint checking
- Momentum management
- Communications
- Health and safety
- Mission management

Flight Data System Software and Hardware Architectures

Ground Station
- Command transmission
- Telemetry Reception

Spacecraft Ops
- Telemetry monitoring
- Commanding
- Orbit determination
- Orbit maneuvers

Spacecraft Data Processing
- Data storage
- Trend analysis
- Anomaly investigation

Mission Operations

Science Planning
- Program Selection
- Guest Observer assistance
- Target list generation

Science Processing
- Calibration
- Instrument Trending
- Data annotation

Science Storage and Distribution
- Data archiving
- User data interface

Science Operations

- **Common tools, systems, methodologies**
- **Integrated operations design, optimally distributed across space and ground**

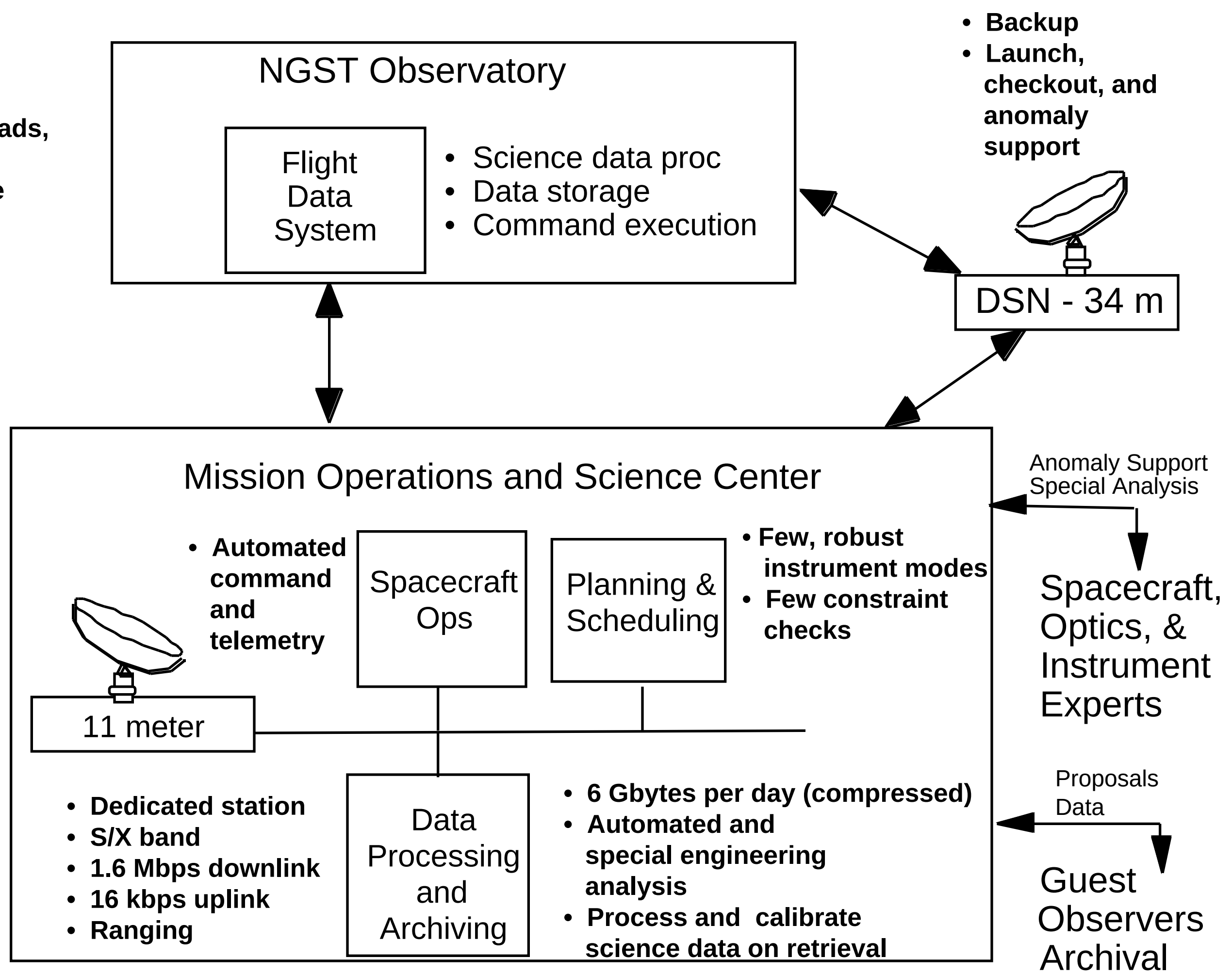
SOME PRINCIPLES AND APPROACHES THAT PROMOTE OPERABILITY IN NGST
(FROM THE GSFC FEASIBILITY STUDY)

- **CONCURRENT FLIGHT AND GROUND SYSTEM DEVELOPMENT**
- **AN INTEGRATED SCIENCE MODULE**
- **LIMITED, WELL-DEFINED INSTRUMENT MODES**
- **MISSION-DURATION MARGINS IN ON-BOARD EXPENDABLES**
- **SCRIPT-DRIVEN MISSION EXECUTION WITH POSITIVE COMMAND RESPONSE REPORTING**
- **INFREQUENT USE OF ABSOLUTE-TIME-TAGGED COMMANDS**
- **FOCUSED APPLICATIONS OF AUTONOMY**
  (E.G., FOR MOMENTUM, SLEW, ANTENNA AND ATTITUDE MANAGEMENT)
- **FILE MANAGEMENT OF ON-BOARD DATA AND SPACE/GROUND DATA TRANSFERS**

OPERATIONS TRADES AND MISSION DESIGN - AN EXAMPLE

- Common software components, standards
- File to file transfers of loads, observation data
- Simple, robust safemode
- Select autonomy

- All functions colocated
  - reduced comm costs
  - cross-trained ops
  - common data bases
  - single cmd generator
  - common science and engineering archive
  - no contention for station



- Self-sufficient except for DSN backup

NGST OPERATIONS
AN OBSERVATION PLANNING FLOW

- Time frames are examples; most activities are operations-model insensitive

T-1 Year to T-9 mo.	T-9 mo. to T-6 mo.	T- 6 mo. to T-1 day	Weekly - Daily
Science Program Selection	Proposal Development and Initial Activity Ordering	Activity Ordering and Proposal Updates	Command File Generation, Validation, and Uplink

Science Program Selection

- Time Allocation Committee
- Electronic Review and Teleconferencing

Proposal Development and Initial Activity Ordering

- Remote Development by Observer using NGST Provided Tools
- Predefined Observation templates
- Observation data rate model and limits
- SNR and Exposure Time Estimator
- Target visibility and viewing constraint checks
- Target Acquisition Planner

Scientist's Expert Assistant Functions

Activity Ordering and Proposal Updates

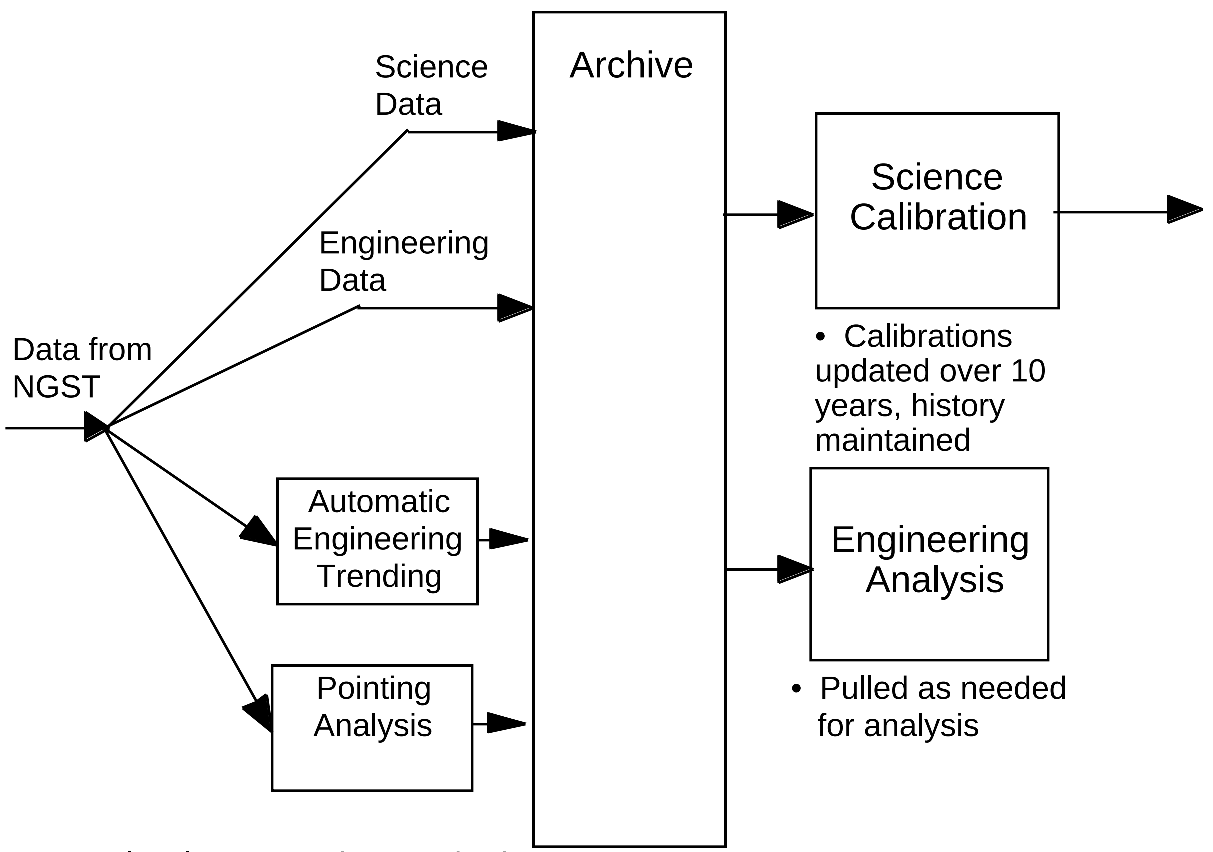
- Viewing Constraint Checking
- Parallel Observation Scheduling
- Data Rate Validation
- Slew Duration/distance Management (to increase efficiency)
- Incorporate Special Operations
- Observation Updates
- Just-in-time additions

Command File Generation, Validation, and Uplink

- Ordered List of Observation Files for each NGST pointing
- Generation of All Parameters and Arguments for Onboard Macros

Adaptive Scheduler Inputs

NGST OPERATIONS
A SCIENCE AND ENGINEERING DATA PROCESSING FLOW



- Calibrations updated over 10 years, history maintained
- Pulled as needed for analysis

- Data “pushed” to observer
- Data “pulled” by archival researcher
- “WWW-like” access to catalog
- Raw and calibrated data provided to user

- No level 0 processing required

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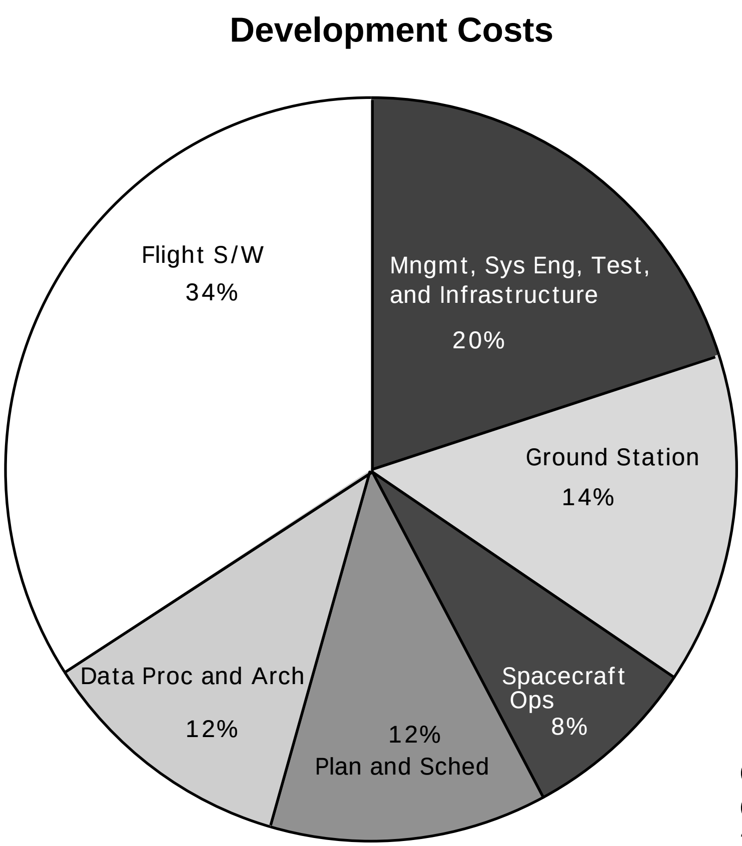
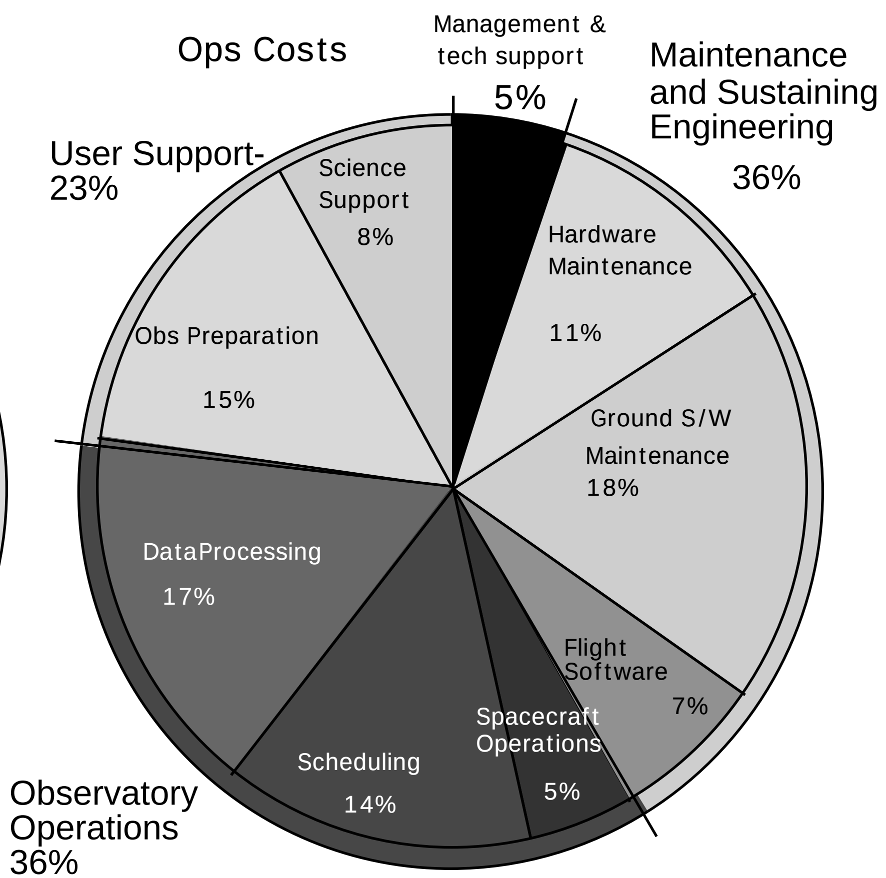
NGST OPERATIONS COST ELEMENTS

- Technology process should be influenced by cost drivers
- Our current efforts are targeted accordingly





- Flight software is biggest component

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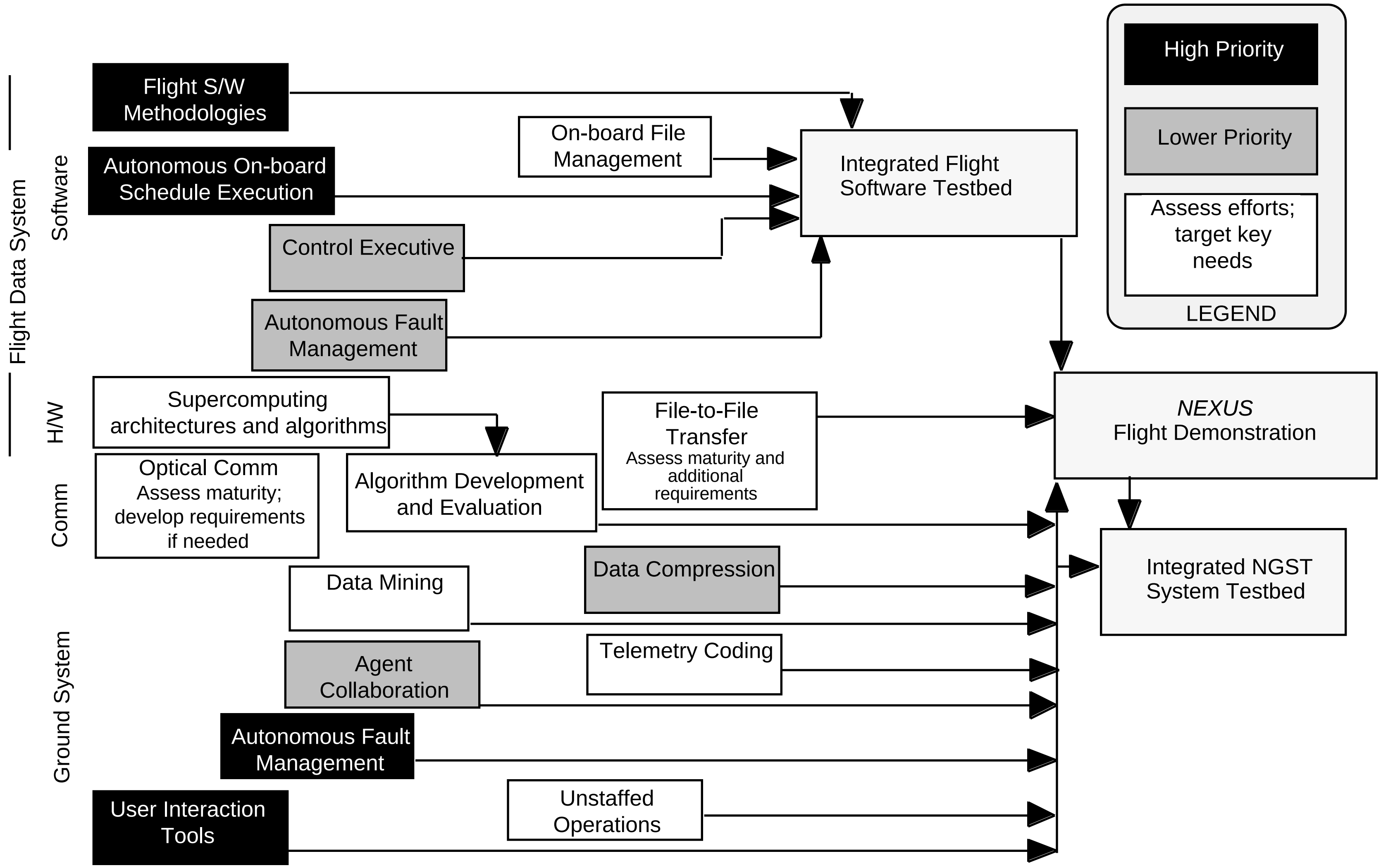
NGST OPERATIONS TECHNOLOGY OBJECTIVES



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NGST SCIENTIST'S EXPERT ASSISTANT

- **OBJECTIVE: WITH NEW/EMERGING INFORMATION SYSTEM TECHNOLOGIES, SIMPLIFY THE OBSERVATION DESCRIPTION PROCESS**
  - **SHORTEN OBSERVER LEARNING TIME; REDUCE ERRORS**
- **COMPONENTS:**
  - **GRAPHICAL/VISUAL TOOLS TO FINE-TUNE OBSERVATION**
  - **RULE-BASED TOOLS FOR DETERMINING INSTRUMENT PARAMETERS**
  - **DATA MINING TECHNIQUES TO SEARCH FOR, RETRIEVE AND LEVERAGE PRE-EXISTING IMAGE DATA**
  - **AGENT TECHNOLOGY TO SCREEN PENDING OBSERVATIONS FOR IMPACTS OF CHANGED INSTRUMENT PERFORMANCE**
- **3-YEAR MULTI-PHASE EFFORT**
- **IMPLEMENTING PROTOTYPE FOR THE HST *ADVANCED CAMERA FOR SURVEYS***

NGST ADAPTIVE SCHEDULER

- OBJECTIVE: INCREASED SPACECRAFT AUTONOMY AND OPERATIONAL EFFICIENCY WITH EVENT-DRIVEN MANAGEMENT AND EXECUTION OF MACROS AND SCRIPTS
  - SIMPLIFIES GROUND MODELING AND SCHEDULING
  - ELIMINATES USE OF ABSOLUTE-TIME-TAGGED COMMANDS
  - MANAGES SLEWS AND TARGET ACQUISITIONS; STARTS AND ENDS EXPOSURES; CONTROLS AUXILIARY ENGINEERING ACTIVITIES (E.G., ANGULAR MOMENTUM DUMPS AND COMMUNICATIONS) AUTONOMOUSLY
  - SIMPLIFIES REORDERING/REPLACEMENT OF PLANNED EXPOSURES
- PROTOTYPE DEVELOPMENT UNDERWAY
- LIKELY COMPONENT OF *NEXUS* FLIGHT DEMONSTRATION

OPERABILITY IPT
"TOP 5" ACTIVITIES ('98 - Early '00)

- **CONDUCT AND DOCUMENT KEY OPERABILITY TRADES SUPPORTING THE ARCHITECTURE STUDIES**
- **DEFINE AND EMBARK ON TOP PRIORITY ADVANCES IN FLIGHT SOFTWARE DEVELOPMENT METHODOLOGIES**
- **COMPLETE AND ASSESS THE ADAPTIVE SCHEDULER AND SCIENTIST'S EXPERT ASSISTANT PROTOTYPES**
- **IDENTIFY AND SUPPORT OR BEGIN FOCUSED WORK ON OPERATIONS TECHNOLOGY ADVANCES OF PARTICULAR SIGNIFICANCE TO NGST**
- **DEFINE AND DOCUMENT THE MISSION OPERATIONS REQUIREMENTS FOR NGST**
  - **DEFINE THE CORRESPONDING OPERATIONS MODEL FOR *NEXUS***

NGST OPTICS TECHNOLOGY PROGRAM

Jim Bilbro

Optics IPT Lead

NGST OPTICS TECHNOLOGY PROGRAM

AGENDA

- OBJECTIVE
- KEY TECHNOLOGIES
- ROADMAPS
- REQUIREMENTS
- GOALS
- SUMMARY

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NGST OPTICS TECHNOLOGY PROGRAM

OBJECTIVE

DEVELOP AND DEMONSTRATE THE KEY OPTICAL TECHNOLOGIES REQURIED TO ENABLE THE NEXT GENERATION SPACE TELESCOPE

NGST OPTICS TECHNOLOGY PROGRAM

NGST OPTICS TECHNOLOGY PROGRAM

- **The NGST challenge**
  - 10 X the collecting area of HST
  - 25% the mass of HST
  - 25% the life cycle cost of HST (in FY'96$)
- **The technology program must**
  - aggressively develop of enabling technologies for NGST
  - help demonstrate that NGST can be built
  - help demonstrate that NGST can be implemented for a reasonable cost
- **The good news**
  - four independent studies suggest the job can be done!
- **Early investment in technology is essential**

Next Generation Space Telescope

NGST OPTICS TECHNOLOGY PROGRAM

OPTICS IPT

Optics Technologist : J. Bilbro/MSFC
Deputy Optical Technologist: E. Montgomery/MSFC

COI NMSD Team
UoA NMSD Team
TBD Beryllium Mirror Team

Actuator Team/TBD
D.M. Team/TBD

Industrial inputs

HDOS
Kodak
REOSC
ZEISS
IABG
Shafer
SSG
Morton international
Dornier
Schott
Corning
Xinetics

Actuator

Garnett Horner/LaRC
John Varnish/GSFC
Bob Shave/JPL

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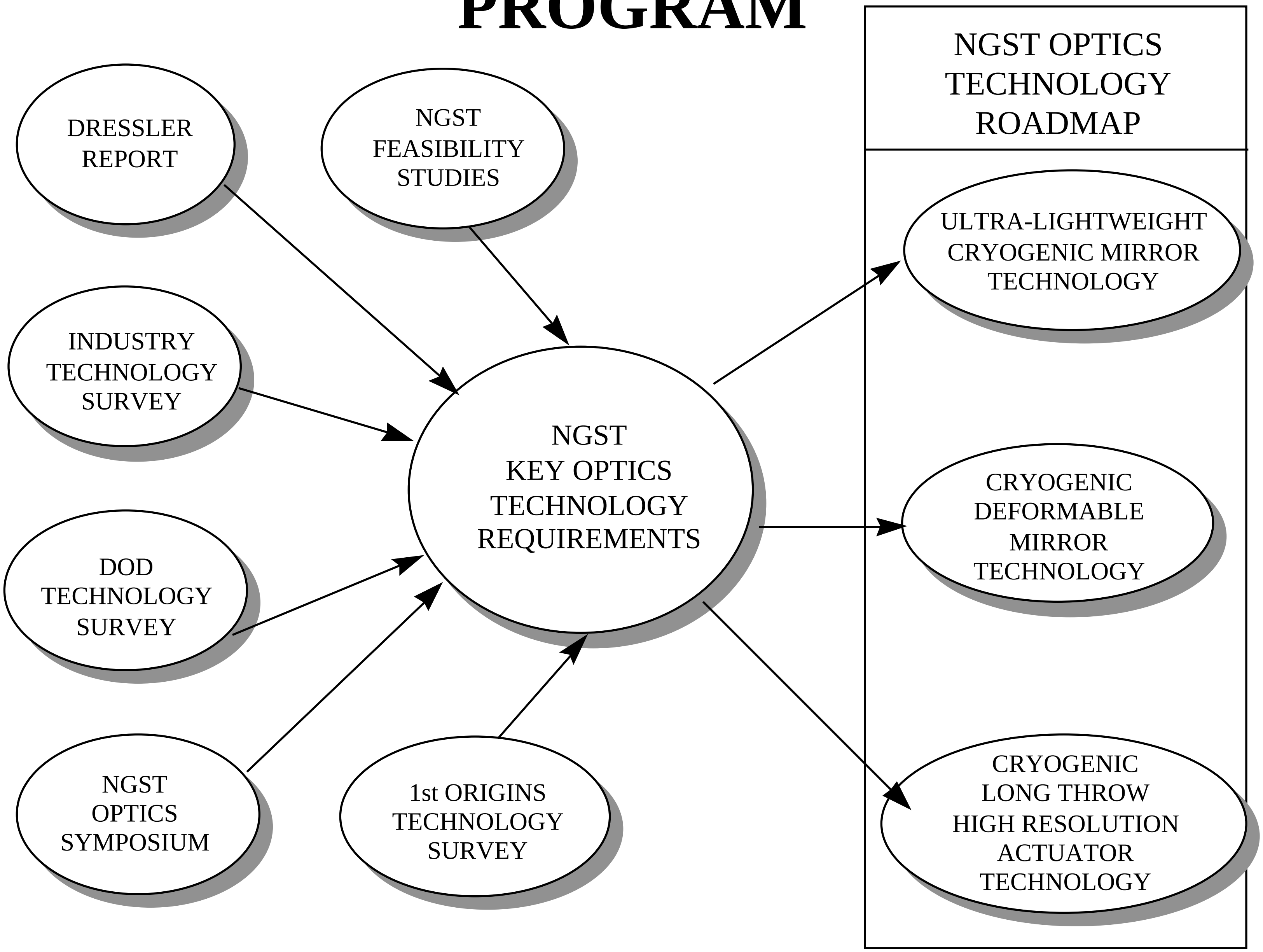
NGST OPTICS TECHNOLOGY PROGRAM



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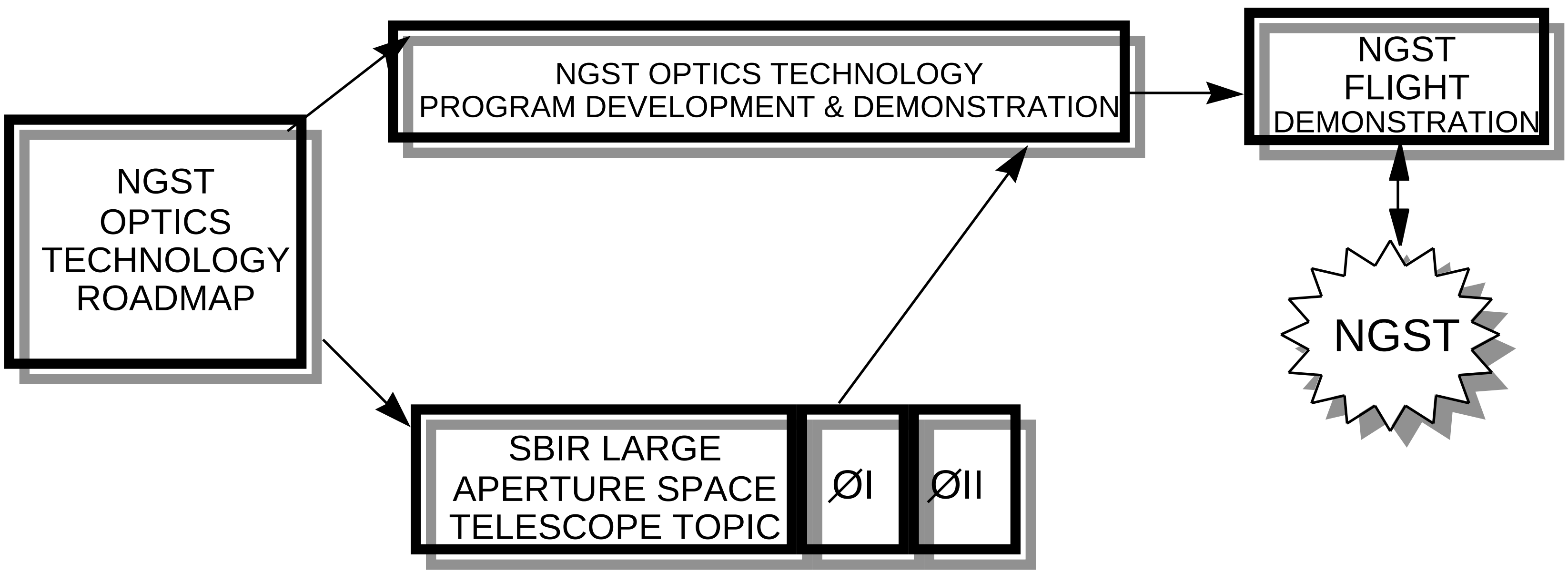

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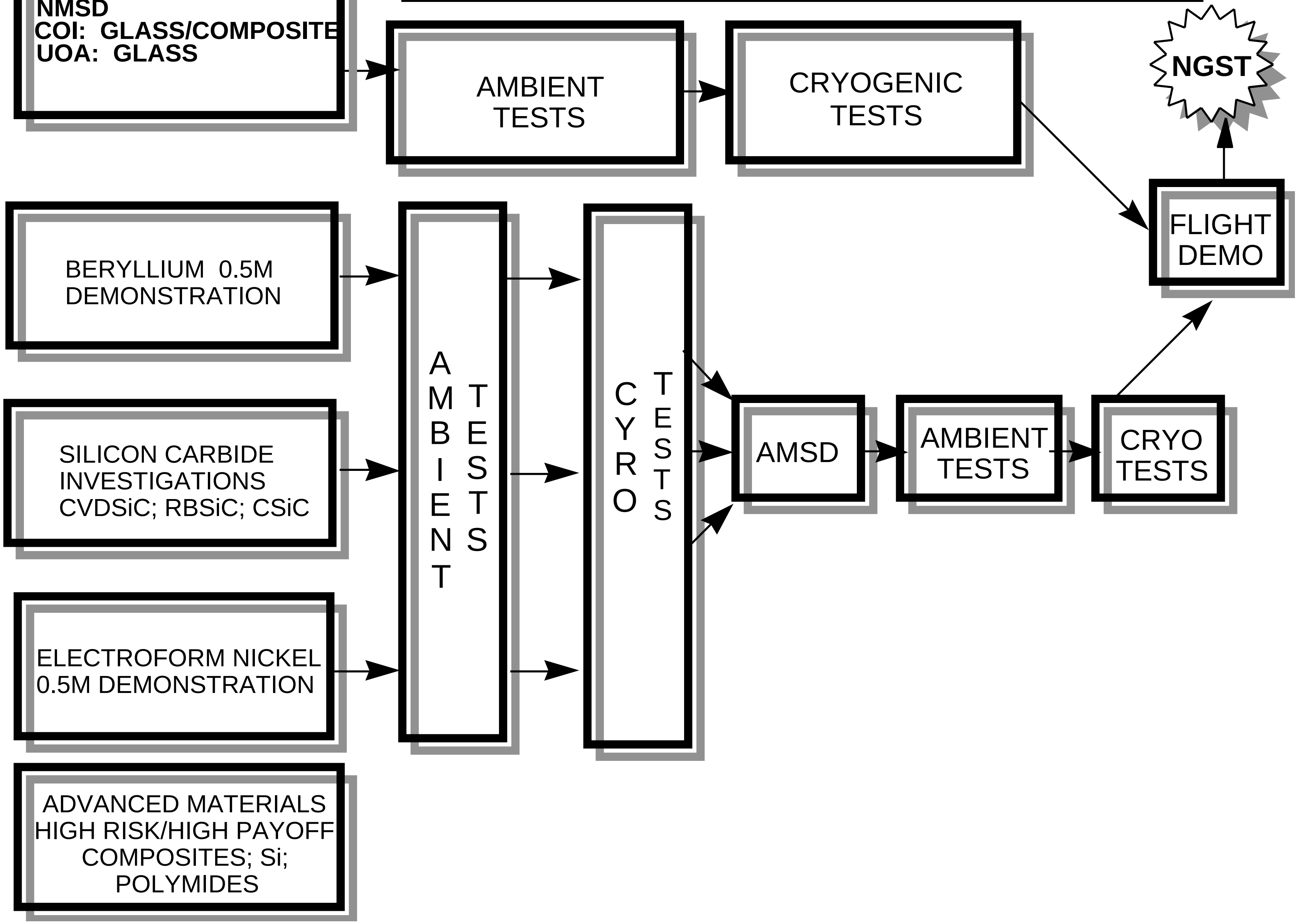
ULTRA-LIGHTWEIGHT MIRROR TECHNOLOGY ROADMAP



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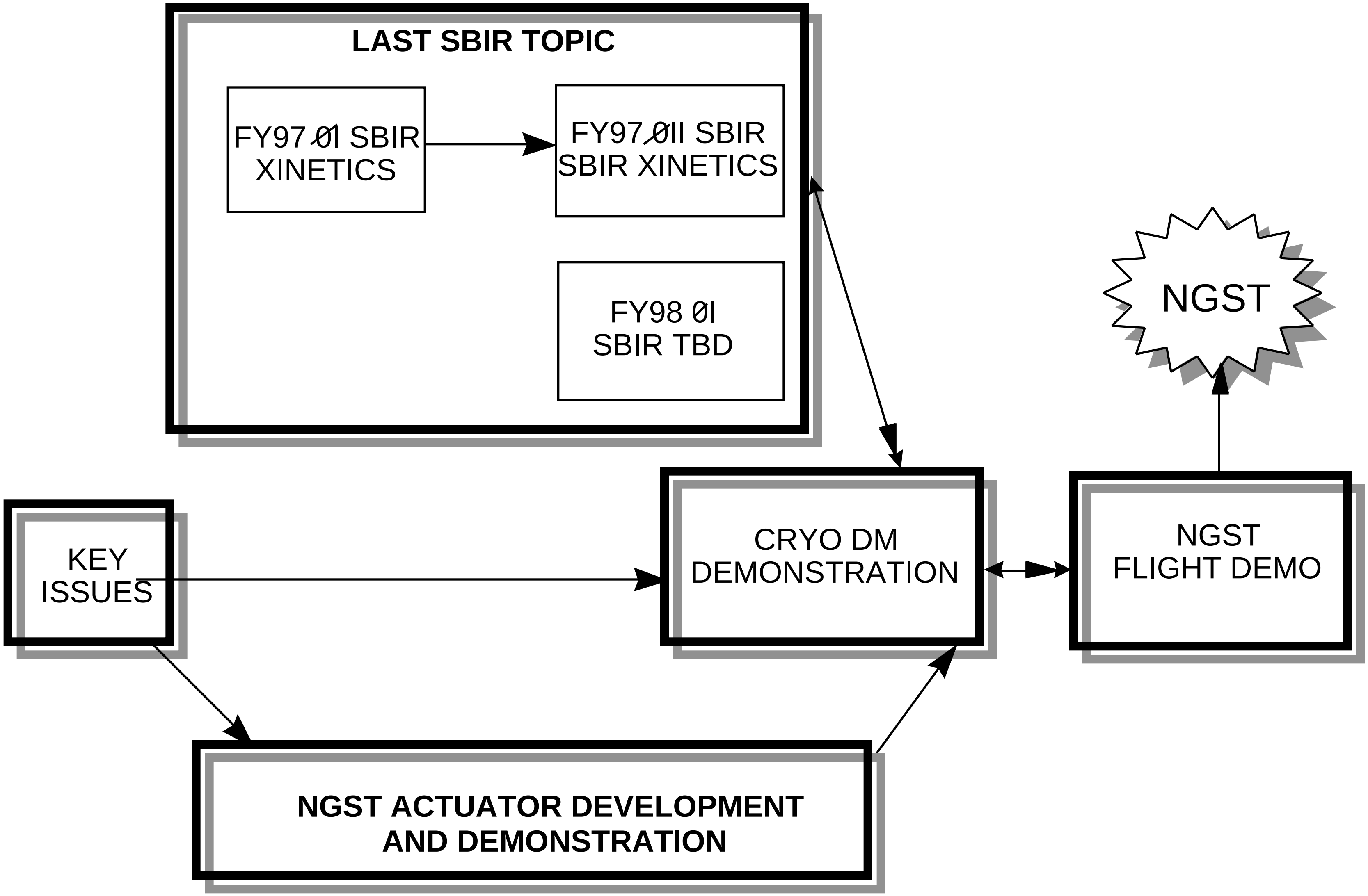
CRYOGENIC DEFORMABLE MIRROR ROADMAP



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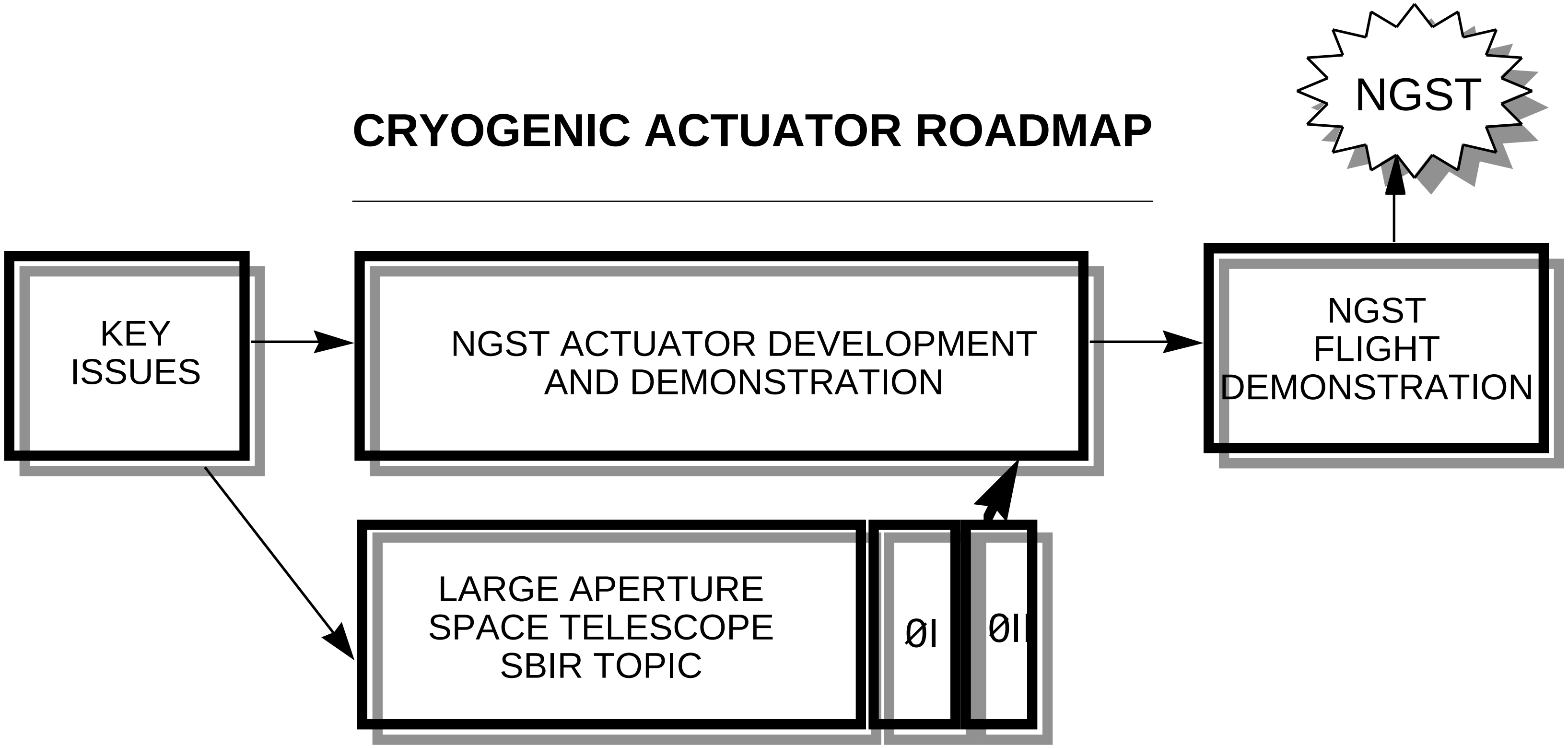
CRYOGENIC ACTUATOR ROADMAP



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NGST OPTICS TECHNOLOGY PROGRAM

NMSD COMPOSITE OPTICS INC. TEAM

COMPOSITE OPTICS INC.
HUGHES DANBURY OPTICAL SYSTEM
KODAK

NGST OPTICS TECHNOLOGY PROGRAM

James W. Bilbro
NGST Optics Technologist

Presentation to
NGST Standing Review Board
January 14-15, 1998

Next
Generation
Space
Telescope

NGST OPTICS TECHNOLOGY PROGRAM

PRIMARY MIRROR GOALS

- **DEMONSTRATE AT CRYOGENIC TEMPERATURES AT LEAST TWO VIABLE PRIMARY MIRROR CONCEPTS PRIOR TO THE START OF THE NGST PRIME CONTRACTOR SELECTION PROCESS**

NGST OPTICS TECHNOLOGY PROGRAM

PRIMARY MIRROR SYSTEM REQUIREMENTS

- DIFFRACTION LIMITED OPERATION @ 2 MICRONS
- PRIMARY MIRROR SYSTEM AREAL DENSITY IS < 15 KG/M^2
- OPERATING TEMPERATURE (REQUIREMENT IS 60K (30K GOAL)
- ACCOMMODATIONS DEPLOYABLE TELESCOPE CONCEPTS
- ACTIVE CORRECTION PERMITTED

NGST OPTICS TECHNOLOGY PROGRAM

PRIMARY MIRROR MATERIAL CONSIDERATIONS

- **BERYLLIUM: BEST MATERIAL PROPERTIES -- HAS SIGNIFICANT MANUFACTURING AND COST PROBLEMS**
- **SILICON CARBIDE: NEXT BEST MATERIAL PROPERTIES -- LACKS MATURITY**
- **GLASS: MOST HERITAGE - - LACKS DESIRED RIGIDITY AND HAS HANDLING AND LAUNCH CONCERNS DUE TO FRAGILITY**
- **ELECTORFORMED NICKEL: CHEAPEST COST -- LACKS DESIRED RIGIDITY AND CRYOGENIC PERFORMANCE IS UNDEMONSTRATED**
- **HYBRIDS (MATERIAL COMBINATIONS): RESOLVES RIGIDITY PROBLEMS -- HAS CTE MISMATCH PROBLEMS**

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PRIMARY MIRROR FABRICATION CONSIDERATION

THIN SHELL GRINDING AND POLISHING

- VACUUM LAP POLISHING
- ION FIGURING
- GAS BEARING BLOCKING BODY
- WATER JET MILLING
- NEAR NET SHAPE CASTING

THIN SHELL REPLICATION

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NGST OPTICS TECHNOLOGY PROGRAM

NEXT GENERATION SPACE TELESCOPE MIRROR SYSTEM DEMONSTRATOR

(NMSD STATUS)

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NGST OPTICS TECHNOLOGY PROGRAM

NMSD COMPOSITE OPTICS INC. TEAM

COMPOSITE OPTICS INC.
HUGHES DANBURY OPTICAL SYSTEM
KODAK

NGST OPTICS TECHNOLOGY PROGRAM

NMSD - Mirror/Assembly Requirements

PARAMETER	VALUE	GOAL
Footprint	Circular with one flat edge	
Flat Length	One Half the diameter	
Diameter	>1.5m	2.0m
Shape	Spherical	
F/No.	f/6	f/5
No. of Actuators	As required for figure and/or phasing capability	
Figure	$<\lambda/4$ (λ = .633 micron)P/V	$<\lambda/10$ P/V
Mid-Spacial Errors	$<\lambda/10$ (λ = .633 micron) P/V	$<\lambda/20$ P/V
Mid-Spacial Scale	1 - 10 cm	
Finish	<2.0nm RMS	1.0nm RMS
Areal Density (Mirror Assembly)	15kg/m^2	<15kg/m^2
NMSD Optical Performance		
Simulated Space Environment	70 ^{o}K Min. Temp	35 ^{o}K
NMSD Dynamic Characteristics	TBD	

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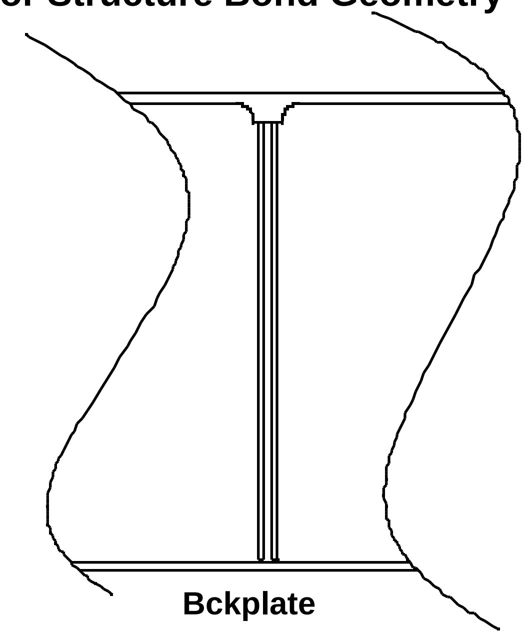
NGST OPTICS TECHNOLOGY PROGRAM

NMSD - COI Primary Mirror Assembly Overview

Mirror Structure Bond Geometry

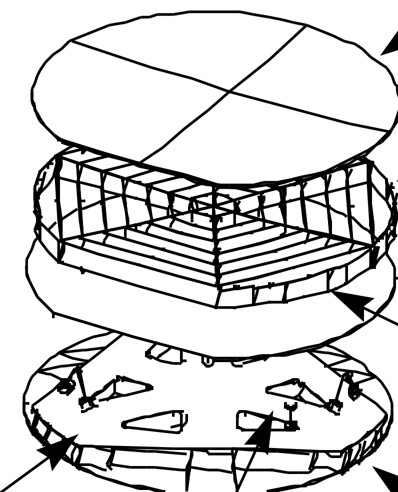
Glass

Core Modules



Bckplate

Isogrid Stiffened Surface (Zerodur) Figured to Meet Requirements at 35ºK



Composite Reaction Structure with Integral Thermal Shield M55J/954-3 Laminate Quasi-Isotrpopic Decks +/-45º Laminate Egg Crate Core

Center Force Actuator (Cryogenic) for Radius of Curvature Correction

Invar Flexures Mounted on Tip/Tilt/Piston Cryogenic Actuators

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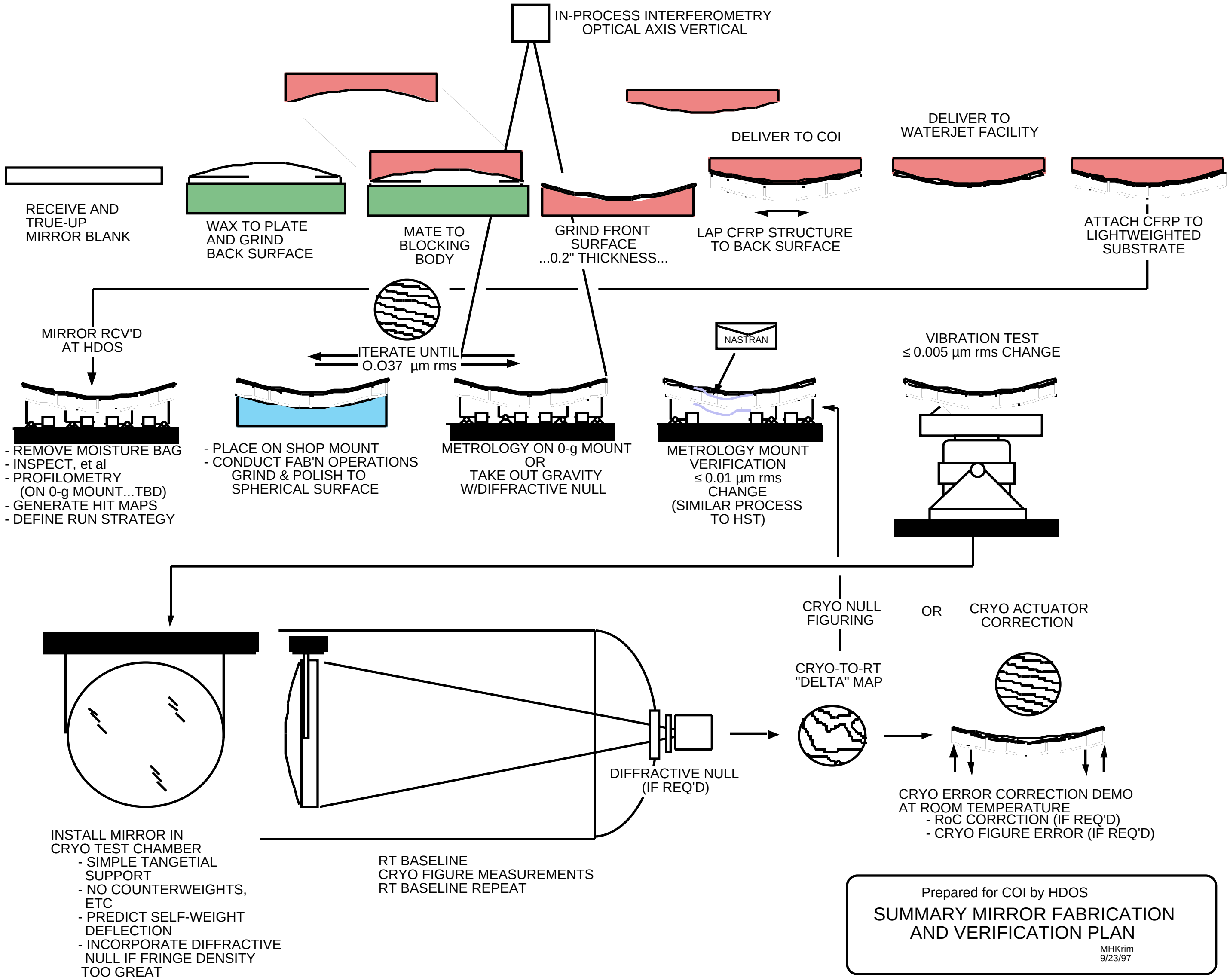
NGST OPTICS TECHNOLOGY PROGRAM

COI - Mirror Fabrication & Test - Overview



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NGST OPTICS TECHNOLOGY PROGRAM

KEY TECHNOLOGIES

- PRIMARY MIRROR
- CRYOGENIC ACUTATORS
- CRYOGENIC DEFORMABLE MIRROR

NGST OPTICS TECHNOLOGY PROGRAM

Deformable Mirror Technology

- **Requirements**
  - **Primary mirror edge mismatch correction not considered feasible/advisable at DM where spatial scales are reduced**
  - **Remaining distortions (thermal, inhomogenous materials) probably correctable with closely packed (2-4 cm) actuators**
  - **Performing all correction on primary mirror segments is remains a viable trade-off against the DM.**
- **Issuers/Investigations**
  - **Considered segmenting DM like the primary - problems in detrails**
  - **Most actuators operate at 10-30% of stroke. 40% concepts have been developed. Actuator program initiated to resolve.**
  - **Material and design of DM facesheet for cryogenic operation an outstanding issue. Phase II SBIR at Xinetics to address.**
  - **Reducing electronics footprint, power consumption/thermal output, and mass an issue. Blue Line phase II SBIR underway and other phase I SBIR proposals in hand.**
- **Development of NGST demonstrator delayed due to lack of funds**

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NGST OPTICS TECHNOLOGY PROGRAM

Actuator Requirements

Property	Type 1 Requirement	Type 1 Goal	Type 2 Requirement	Type 2 Goal
Resolution (nanometer)	≤20	≤10	≤20	≤10
Lifecycles	≥10,000	≥100,000	≥10,000	≥100,000
Stroke (mm)	≥0.3	≥0.5	≥6	≥10
Operating temperature range, (Kelvin)	20-60	20-300	20-60	20-300
CM Heat dissipation, (milliwatts)	≤5	≤0.5	≤5	≤0.5
OM Heat dissipation, (milliwatts)	≤0.05	≤0.005	≤0.05	≤0.005
Mass (grams)	≤40	≤20	≤40	≤20
Outside Diameter, (cm)	≤2	≤1	≤5	≤1
Creep, OM (nm/day)	≤0.1	≤0.01	≤0.1	≤0.01
Thermal stability, OM (nm/K)	≤50	≤20	≤50	≤20
Axial Force, set & hold, OM (N)	≥0.5	≥1.0	≥0.5	≥1.0
Power Consumption, CM, (watt)	≤1.0	≤0.1	≤1.	≤0.1
Axial Stiffness, (N/micron)	≥1.0	≥1.0	≥1.0	≥1.0
Stowed Axial Length, (cm)	≤10.0	≤10.0	≤10.0	≤10.0

Property	Type 3 Requirement	Type 3 Goal
Resolution (milliNewton)	≤4	≤2
Lifecycles	≥10,000	≥100,000
Peak-to-peak Force, (Newton)	≥4	≥2
Operating temperature range, (Kelvin)	20-60	20-300
CM Heat dissipation, (milliwatts)	≤5	≤0.5
OM Heat dissipation, (milliwatts)	≤0.05	≤0.005
Mass (grams)	≤100	≤50
Outside Diameter, (cm)	≤5	≤2
Thermal stability, OM (mN/K)	≤0.6	≤0.4
Stroke, (mm)	≤.5	≤.8
Creep, OM (mN/day)	≤0.6	≤0.4
Axial stiffness, OM (N/m)	≤15	≤10
Power Consumption, CM, (watt)	≤1.0	≤0.1
Stowed Axial Length, (cm)	≤10.0	≤10.0

Property	Type 4 Requirement	Type 4 Goal
Resolution (nanometer)	≤5	≤3
Lifecycles	≥100,000	≥1,000,000
Stroke (μm)	≥100	≥200
Operating temperature range, (Kelvin)	20-60	20-300
CM Heat dissipation, (milliwatts)	≤5	≤0.5
OM Heat dissipation, (milliwatts)	≤0.05	≤0.005
Mass (grams)	≤20	≤10
Array column & row spacing, (mm)	≤1	≤0.5
Array size, number of actuators	(≥10)x(≥10)	(≥50)x(≥50)
Creep, OM (mN/day)	≤0.6	≤0.4
Thermal stability, OM (nm/K)	≤100	≤20
Axial Force, OM, (Newton)	≥0.5	≥1
Power Consumption, CM, (watt)	≤1.0	≤0.1

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NGST OPTICS TECHNOLOGY PROGRAM

Cryogenic Actuators

Objective: To develop commercial capability to provide cryogenic actuators for NGST that are reliable, cost effective, and meet NGST mission requirements

Approach: Fund industry, academia, and government to develop actuators via a competive procurement, RFO

NGST OPTICS TECHNOLOGY PROGRAM

Cryogenic Actuators

- NGST Unique Requirements-

- 20 nanometer resolution
- 6 mm stroke capability
- 20-60K operating temperature
- Power-off, set and hold capability
- Low power consumption to operate
- Negilible heat dissipation

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Cryogenic Actuators

- RFO Features-

- Four actuator types
  - Shape and position control actuators
    - Short stroke (not a mechanism)
    - Long stroke (“inchworm” like mechanism)
  - Force control actuator
  - Deformable mirror actuator array
- Phased procurement
  - Design phase (Phase 1, *4 mo.*)
  - Fabricate, analyse, and test (Optional Phase 2, *14 mo.*)

NGST OPTICS TECHNOLOGY PROGRAM

Cryogenic Actuators

- RFO Status-

- 12 Proposals from 8 companies received
- Proposals have been evaluated and competive range has been determined
- Expect selection by 1/12/98
- Awards to follow ASAP

NGST Infrared Detector Technology Development

Craig McCreight
NASA Ames

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Outline -- Detector Technology

- Goals & Objectives
- Development Approach / Philosophy
- Performance Requirements
- Present Development Activities
- Planned Development Activities
- Budget / Milestones

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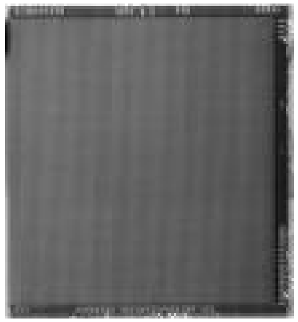
Objectives

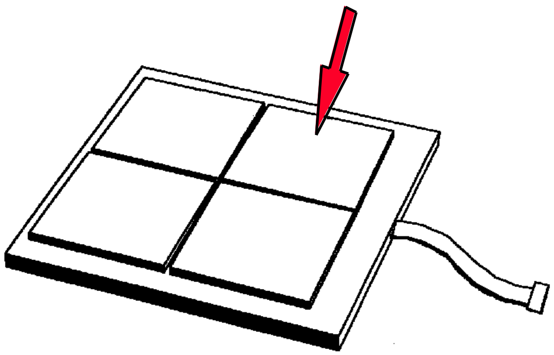
- Develop <u>multiple</u> technology options which meet NGST requirements; in near-IR and thermal-IR
- Follow stategies outlined in NGST Detector Development Plan, and at Origins Technology Workshop
- Incorporate prior low-background art & science (e.g., SIRTF), while also looking for new, emerging technologies
- Carefully characterize and demonstrate technologies (lab, telescope, space?)
- Involve science community in development and demonstration phases

NGST Detector Development Plan

- Goals: Meet science goals by demonstrating
  - Improved sensitivity (lower i_{dark}, read noise)
  - Increased formats, w/ 512^2 up to $2k^2$ building blocks
- Approach: Plan technology development with
  - Open competition, peer review, science involvement
  - Present work (incl. extensions of SIRTF InSb and Si:As)
  - Planned work (incl. pursuing higher-T TIR options)
- Funding: Approx $12.5 M investment, over 6 yrs
- Deliverable: Flight prototype arrays (NIR, TIR) in ‘02

Building block array



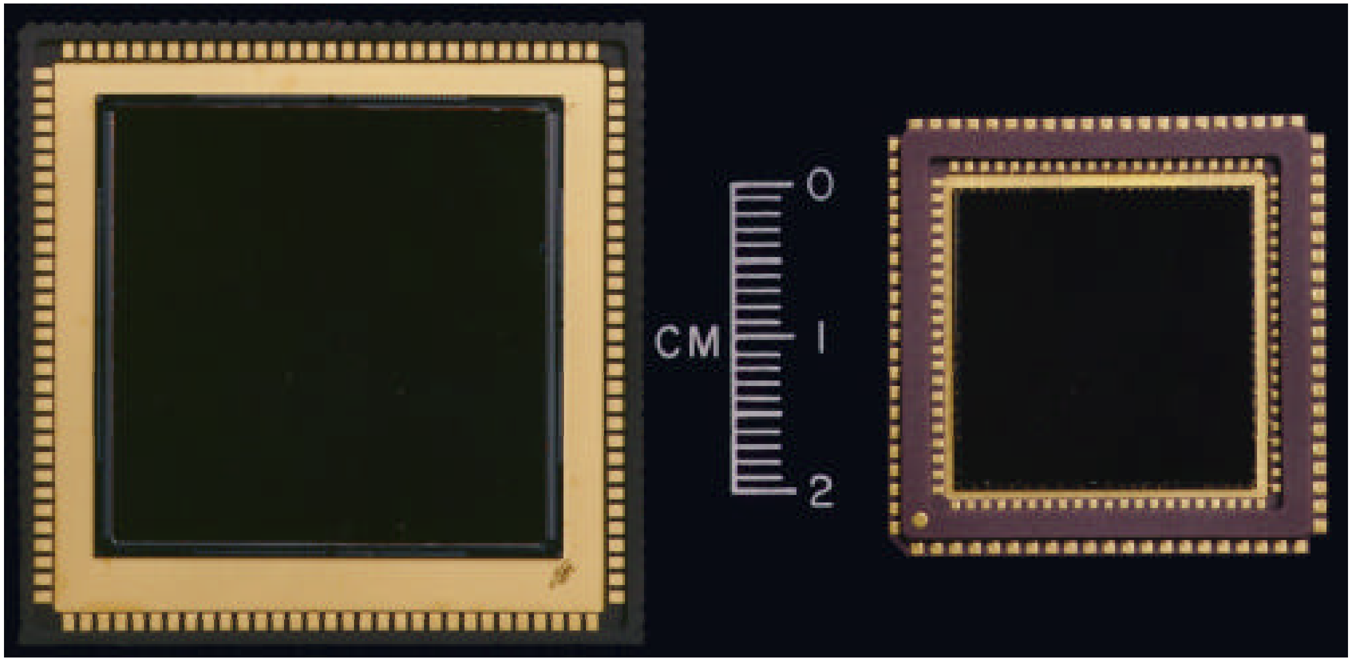


Flight prototype concept

Performance Requirements

Parameter	SOA	NGST Goal	Improvement Factor
1- 5 µm (core)			
Format	1k x 1k HgCdTe & InSb (ALADDIN, HAWAII)	2k x 2 k, to 4 k x 4 k	4 - 16 x pixels
	256 x 256 InSb (low-background)	2k x 2 k, to 4 k x 4 k	64 - 256 x pixels
Quantum Efficiency (%)	~80	>90	1+ x
Read Noise (e^-)	~5	3	2 x
Dark Current (e^-/s)	0.1 (InSb)	0.01 - 0.1	≤10 x
Rad Hardness	Apparently OK for 1 AU	TBD	?
5 - 20 µm			
Format	256 x 256 Si:As IBC	1k x 1 k	2 - 4 x
Quantum Efficiency (%)	~40	>70	2x
Read Noise (e^-)	~10	~3	3 x
Dark Current (e^-/s)	<2	0.05 (res ~1000) to <10 (res ~3)	1 - 40 x
Rad Hardness	Apparently OK for 1 AU	TBD	?
Precision & Stability	1-2%?	?	?

Sample Present-Day Large-Format, Ground-Based IR Arrays. 1024 x 1024 pixels



ALADDIN
5.3 µm cutoff InSb
Santa Barbara Research Center

HAWAII
2.5 µm cutoff HgCdTe
Rockwell Science Center

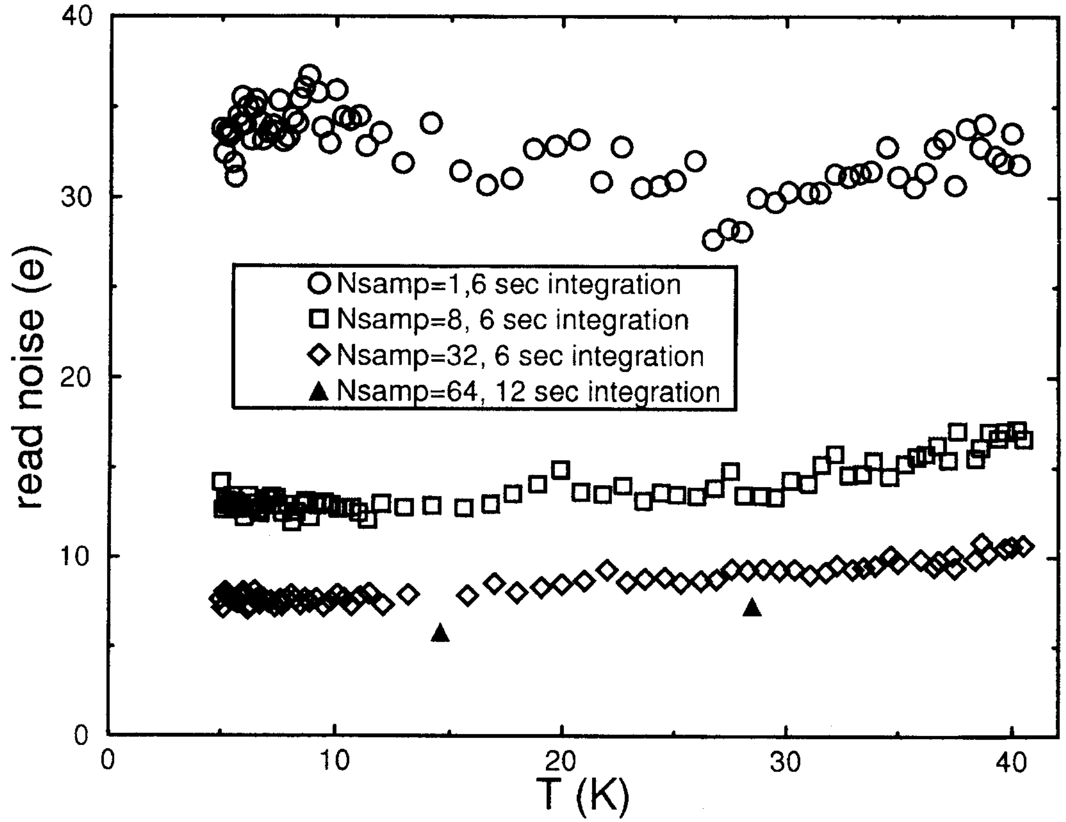
Present Development Activities

- Key NGST development projects selected in peer-reviewed NRA (96-OSS-07). Start date: summer ‘97.
- Large-format InSb arrays *(SIRTF heritage)*
  - Develop buttable 1k x 1k arrays, with <3 e- read noise and 0.01 e-/s dark current
  - W. Forrest, U Rochester, PI; J. Pipher Co-I
  - Team with Santa Barbara Research Center & NASA Ames
  - $466 K 1st yr; 3-yr program
- Large-format Si:As impurity band conduction (IBC) arrays *(SIRTF heritage)*
  - Develop 256 x 256 and 1k x 1k arrays, with <3 e- read noise and 0.05/10 e-/s dark current
  - C. McCreight, ARC, PI
  - Team with SBRC, Cornell, and UR
  - $480 K 1st yr; 3-yr program
- Arrays of HgCdTe (10 µm) for NGST
  - Develop HgCdTe detrs & arrays, T ~ 25-30 K, understand & reduce (to ~100 e-/s) dark current
  - J. Pipher, U Rochester, PI ; W. Forrest Co-I
  - Team with Rockwell Science Center (Thousand Oaks)
  - $286 K 1st yr; 3-yr program

Status: Present Development Activities

- All three initial development projects were presented at NGST Tech Challenge Review in July ‘97.
- Large-format InSb arrays
  - 1st-year focus on reducing noise, with improved readouts. Identified 2 - 3 leading candidates for lot splits -- modifications of basic unit cell circuit. Readout designed & laid out (coordination with Si:As).
- Large-format Si:As IBC arrays
  - Defined and laid out next generation readout for IBC array: 412 x 512 pixels. Readout & detector substrate designed & laid out (coordination with InSb).
- Arrays of HgCdTe (10 µm) detectors
  - Recent series of selected arrays, on NICMOS muxes, under test. Defining design optimizations for lower dark current.

Recent InSb Data (U Rochester)



Demonstrates read noise approaching NGST goals achieved via multiple sampling techniques.
SBRC cryoCMOS Si readouts.

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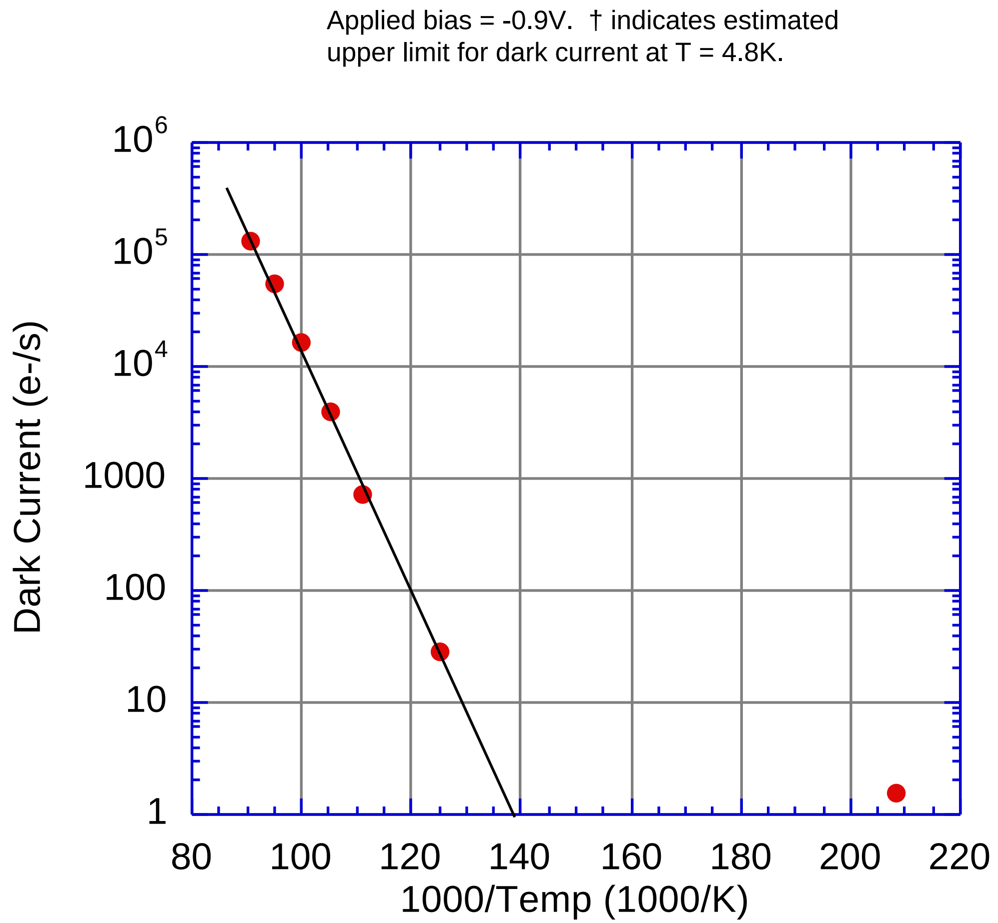
Recent Si:As IBC Dark Current Data (ARC)

256 x 256 Si:As IBC Array

Demonstrates SIRTF-level (& NGST) dark currents within reach.



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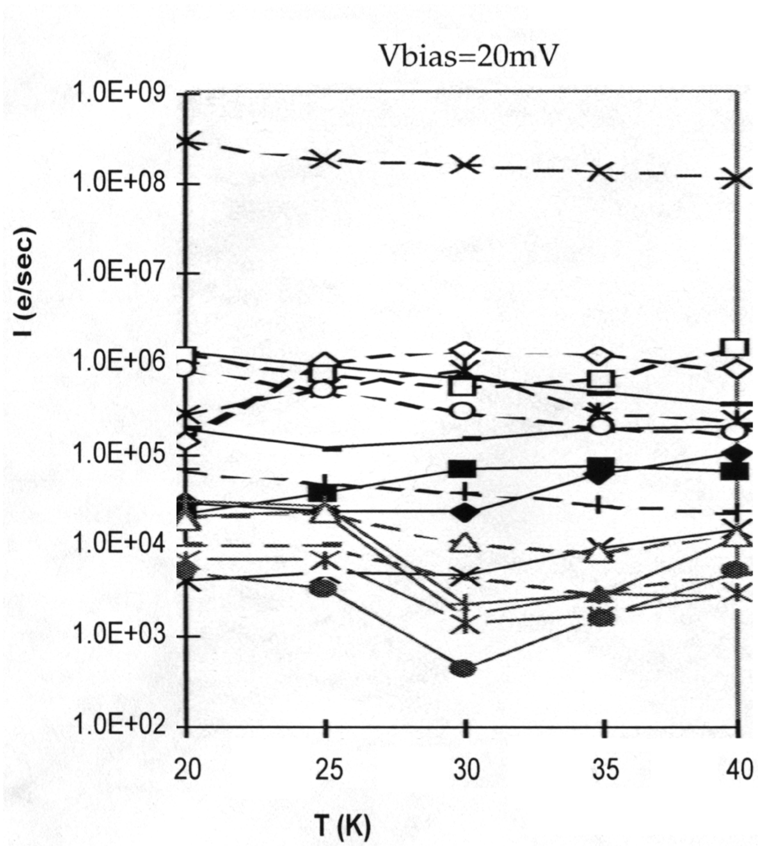
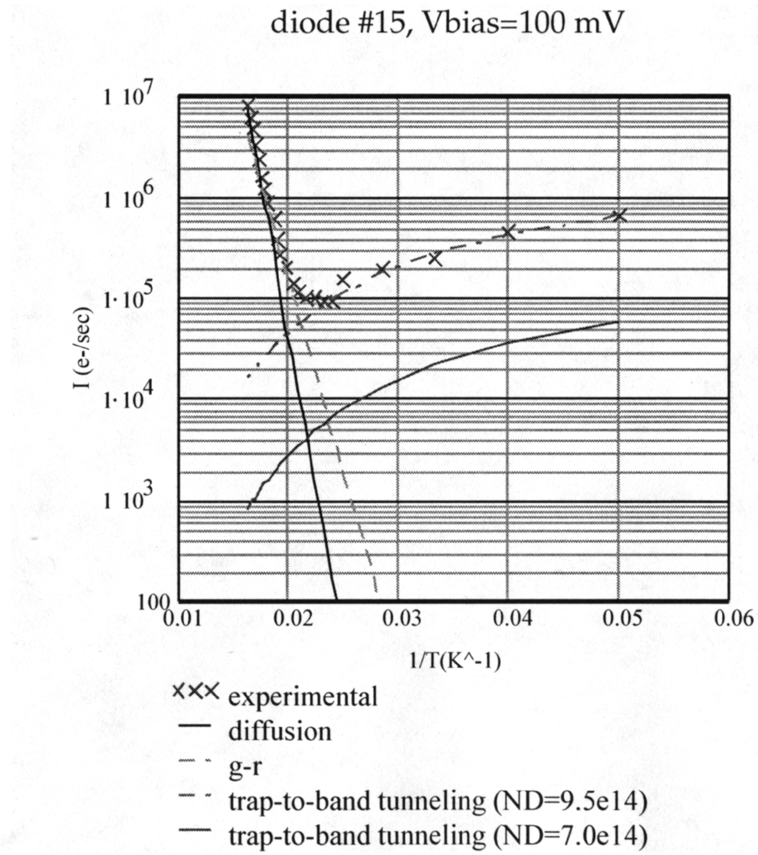
Recent 10 µm HgCdTe Data (UR/Rockwell)





Selected diodes, at 30 K, starting to approach dark current region of interest.

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Planned Additional Activities

- Highly-challenging NGST detector goals call for additional options and technology choices / sources.
- This year we will competitively select one additional activity for near-IR, and one for thermal-IR.
  - Near-IR possibilities: 5 µm HgCdTe, alternate InSb, etc.
  - Thermal-IR possibilities: Alternate Si:As IBC or 10 µm HgCdTe, quantum well technology, Si:Ga IBC, etc.
- Release date: early 1998; award ~May '98.
- Annual funding level: about equal to that of the 3 existing activities.
- Development duration: 2 - 3 years
- Additional detector development possible under industry-directed technology program

Budget / Milestones

- Budget:
  - Plan continuous support, at ~$1.3 M/yr up to May ‘98, and ~$2-3 M /yr in ‘99, ‘00, ‘01, ‘02.
- Milestones:
  - First-generation arrays in late 1998
  - Optimized arrays in late ‘99 and ‘00.
  - Further demonstate arrays (including readouts) in butted-format, in laboratory, and in science instrument testbed: 2000 - 2002.
  - Deliver proven technology options at Phase B start, late 2000.

ESA NGST Activities for 1998

Overview and Planning

Koos Cornelisse
NGST Study Manager
Future Science Projects
Directorate of Scientific Programmes

ESA Pre-Phase A Activities (1998)

- Technical studies according to recommendations of NGST Task Group (NTG)
- ESA Study Science Team (SST) with US representatives
- Participation of ESA SST members in NASA Ad-hoc Science Working Group
- Participation in NASA Standing Review Board (SRB)
- Organisation/sponsoring of NGST Workshop in Liege
- Coordination with NASA

Technical Studies

- The NGST Task Group (NTG) has recommended that ESA initiate, in close coordination with NASA, the following studies, in order to further define possible ESA contributions to NGST and follow-on activities in Europe:
  - A study devoted to specific aspects of low-background orbits
  - A study of a spectrograph with multi-object and integral field capabilities
  - Astudy devoted to the definition and design of a complete payload instrument suite
  - A study of a deployable telescope
- These recommendations were unanimously endorsed by the SSAC in its meeting of October 28 and by the SPC in its 17/18 November meeting

Low Background Orbits

- Scientific trade-off of alternative orbits (1 * 3 AU orbit; inclined orbit) as compared to baseline L2 orbit ***(SST)***
- Study of launch and orbit transfer concepts, including solar electric propulsion ***(ESOC/Estec)***
- Study of specific critical spacecraft aspects ***(Industry)***:
  - Power supply
  - Telecommunications
  - Attitude control
- The industrial study would be procured via a competitive ITT, or as rider to the infra-red interferometer study (TBC). Budget required: **150 kECU**.

Multi-object/Integral Field Spectrograph

- The NTG has evaluated the scientific interest of European astronomers and assessed the potential interest of instrumentation groups and concluded that a spectrograph with multi-object and integral field capabilities would be highly desirable scientifically.
- Furthermore, this is an area where European groups lead technologically
- **The study objectives are to:**
  - Specify the performance requirements
  - Produce a sufficiently detailed instrument design
  - Evaluate the performance
  - Identify technology development requirements and risks
  - Identify options for extending or descoping
  - Provide estimate of required resources
- It is proposed that the study is procured via a non-restrictive competitive ITT (open to **industry** and **scientific institutes**). Budget required: **200 kECU**

Combined Payload/Telescope Study - Rationale

- **From a technical and scientific standpoint it is desirable that the study of a complete payload instrument suite and the telescope study are combined into one single study encompassing the complete NGST optical configuration:**
  - **Consistent overall optical design conform the identified scientific performance requirements.**
  - **Ease of design and management of interfaces between telescope and scientific instruments.**
  - **Necessity of detectors in focal plane for telescope figure control and accurate and stable telescope pointing**
  - **Desirability of integrating these functions in the payload instruments**

Combined Payload/Telescope Study - Objectives

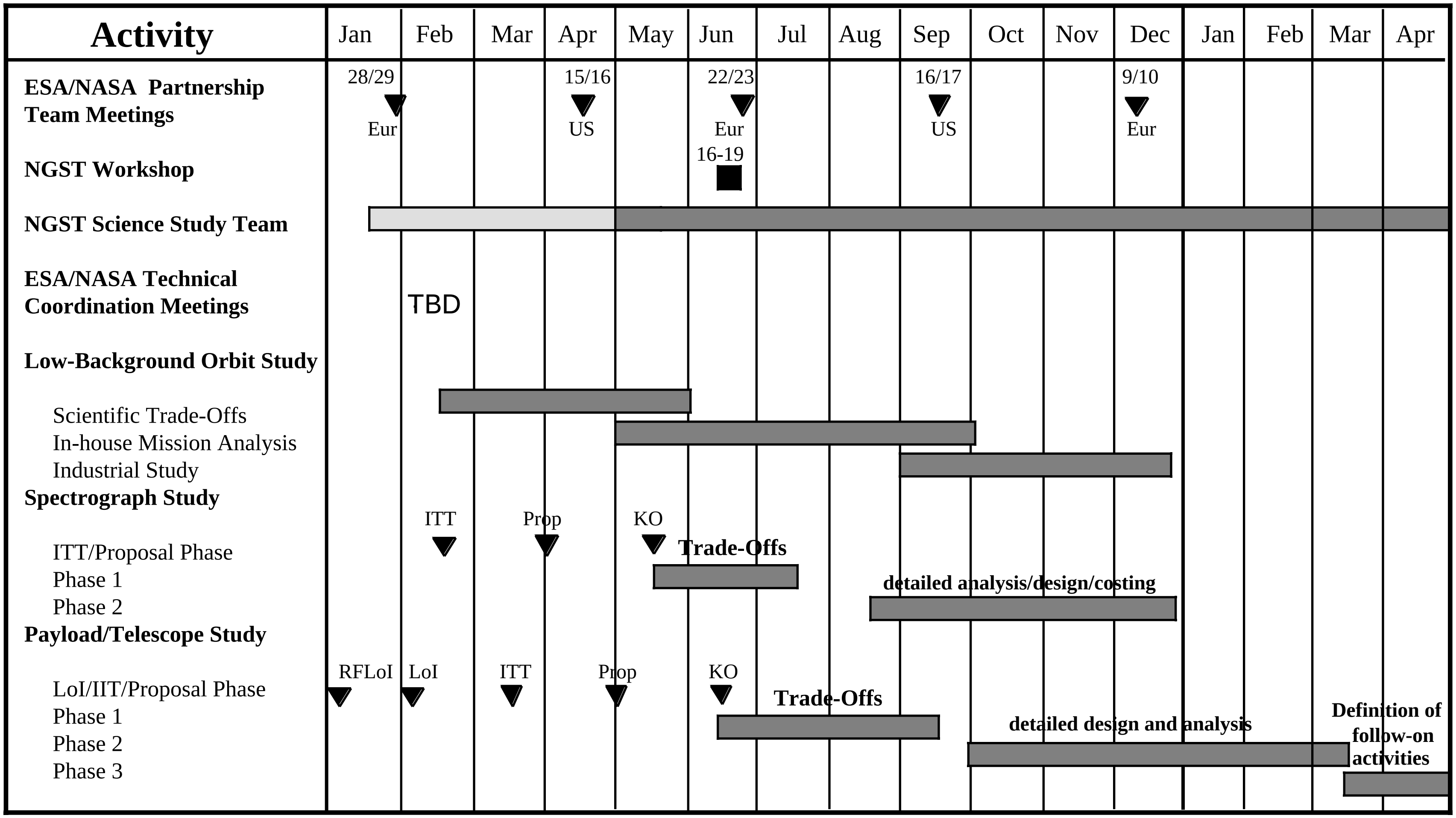
- Define required/desirable payload capabilities and performance from a European perspective and propose an instrument suite
- Define telescope requirements and propose an optical design compatible with the scientific requirements
- Produce preliminary designs of instruments, instrument module and telescope and evaluate overall scientific performance
- Identify areas in which specific (unique) European expertise exist
- Study in detail specific telescope aspects and/or design specific telescope
- Elements (TBD after first study phase in consultation with NASA)
- Propose follow-on activities (in consultation with NASA) and required resources for those

Combined Payload/Telescope Study - Implementation

- It is proposed to procure the study via a single competitive ITT (**750 kECU**)
- The following division of responsibilities is essential:
  - **Industry** (prime)**:** system level aspects, telescope and instrument module
  - **Scientific Institutes:** proposed instrumentation, design of instruments (sub- contractors) and scientific performance evaluation
- A two-step approach is recommended in order to allow potential bidders to establish a consortium with the required expertise in all areas
  1. Inform the Scientific Community of ESA 's intention to issue the ITT and solicit from the community **"letters of interest"**, in which the institute expresses its interest to participate in the study (including a brief description of the proposed instrumentation)
  2. Use the responses in the ITT to define payload instrument options and to identify the interested scientific institutes to potential prime bidders.

Next Generation Space Telescope

NGST 1998 Activities Plan



Program Implementation

Paul Geithner

NGST Systems Engineer

Contents

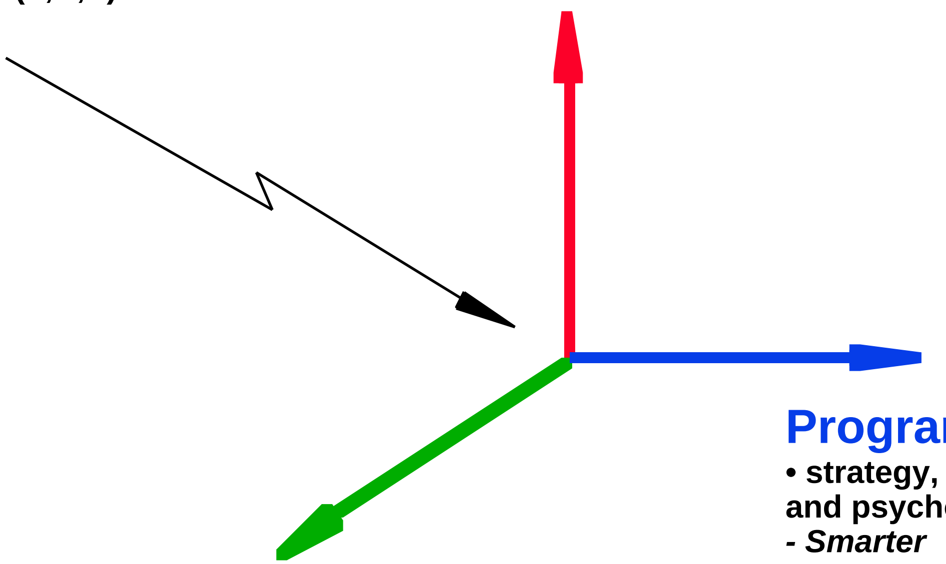
Next Generation Space Telescope

Systems Engineering Trade Space

Technical
- **scientific and technical performance**

- Better

Systems Engineering
$$= \int\int\int f(T,R,P)\, dTdRdP$$



Programmatic
- **strategy, management approaches, and psycho-social dynamics**

- Smarter

Resource
- **money & time, i.e. cost & schedule**

- Cheaper, Faster

Risk is uncertainty in measurable parameters within the trade space, which can be assessed and managed

Next Generation Space Telescope

Metrics

- Unambiguously define targets (so you know where you're going), measure progress (so you know where you are), and determine compliance (so you know if you've made it)
- Enable rational measurement and assessment; move away from idealogy and handwaving and toward the scientific method, logic, and objectivity
- Enable effective contracts and clean agreements
- Allows for quantified, effective cost/benefit analysis

Project Progress Metrics

- **Technical**
  - **Time to complete DRM** **in years**
    - **besides a measure of compliance with project requirements, used to assess need for technological development**
  - **Scientific Relevancy,** **based on ranking by NASA's science advisory committee**
    - **serves as a check on the DRM's vitality**
  - **Technology Readiness Level (TRL),** **where TRLs are NASA definition**
    - **measures technological readiness**
  - **System Performance Effectiveness,** **where performance = speed x FOV / cost**
    - **basis for comparison to other observatories**
- **Resource**
  - **Schedule Milestones** **yes or no**
  - **Schedule and Cost Variance** **according to GAAP, in dollars**
    - **measures compliance with project requirements**
- **Programmatic**
  - **Compliance with Origins theme and strategic plan (ASO)** **yes or no**
  - **Compliance with NASA Procedures and Guidelines (NPG 7120)** **yes or no**

Next Generation Space Telescope

Trades

- Trades regarding programmatic attributes to facilitate reaching project objective at manageable risk
  - organizational structure and membership
  - institutions and partnering
  - management tools
  - government and contractor roles and responsibilities
  - make vs buy guidelines
  - customer and supplier relationships
  - validation approach
  - schedule and phasing
  - investment decisions

Approaches

- **Technical Dimension (easiest to quantify)**
  - **develop diverse portfolio of technologies**
    - **ensure at least 2 validated candidates for every enabling technology before start of development (C/D)**
  - **validate performance with hardware to retire risk early to achieve readiness**
  - **budget requirements thoughtfully and allocate adequate performance margins**
    - **balance must be struck during systems process between conservatism and liberalism. Requires cost/benefit trades to be performed as integral part of design iterations**
  - **Elegant and fault-tolerant design is a must**

Approaches

- **Resource Dimension**
  - Pre-development expenditures on technology >16% results in a mean final overrun of <10%, based on historical data
  - Validate enabling technologies at TRL≥6 before development. Historical analysis shows this typically results in cost overrun containment to <10%
  - Stable funding profile maximizes resources available for value-added effort rather than capital reserves. However, allocate and hold funding and schedule reserves consistent with residual uncertainty

Approaches

- Programmatic Dimension **(hardest to quantify)**
  - ***Cost & Processes IPT chartered to focus here***
  - **apply validated management practices (proven old ones, tested new ones) recruit and retain good people**
    - **put people in positions according to their talents and drive without getting hung-up on home institution**
  - **seek and apply institutional expertise and excellence**
    - **multi-center team has some logistical disadvantages that are outweighed by the benefits of access to the right people and facilities**
  - **establish partnering and buy-in**
    - **use funding to leverage others to contribute their own funding**
  - **reach out to public and scientific community**
  - **advance technological SoA and to maintain scientific significance and technological relevance to future missions**
  - **negotiate “win-win” and use “results-oriented” contracts**

High-Level Trades
Resource

- Historical programs examined to determine cost control/overrun containment as a function of pre-development expenditure

Bernie's chart #24 "Benefit of Study Phase Investment"

Validation

- To meet requirements or achieve goals, new performance capabilities, cost/schedule relationships, and management paradigms must be developed and validated
- Technologies at the component, subsystem, and segment levels will be validated more or less individually
- Nexus Pathfinder Flight is special as *the* system-level technical, resource, and programmatic validation mechanism
  - Limited utility as a technology validator, but given the intrinsic value of building a flight system, it will likely flush-out and validate systems integration issues and technologies. Validity dependent on basic architectural kinship to NGST
  - Important resource validation, where degree of validity and fidelity is function of scaling law credibility and technical similarity
  - Programmatic relevance and degree of validity is a function flight build teaming and process similarity between Nexus and NGST

NGST

Project Organization

STUDY SCIENTIST

J. MATHER, CHIEF
E. SMITH, DEPUTY

NGST STUDY TEAM

B.D. SEERY
PROJECT MANAGER

AD HOC SWG

J. MATHER, GSFC
H.S. STOCKMAN, STScI
CO-CHAIRS

COST & PROCESS IPT

STRETCH IPT

OUTREACH

PROJECT SUPPORT

ARCHITECTURE STUDIES

P. BELY, STSCI
MISSION ARCHITECT

Reference Architecture
P. Bely, STScI

Ball
W. Meyer

TRW
C. Lillie

LMMS
A. Duncan

SYSTEMS ENGINEERING

P. GEITHNER, GSFC
PROJECT SYSTEMS ENGINEER

Operability IPT
K. Kalinowski, GSFC

Science Instrumentation IPT
P. Bely, STScI

OTA IPT
D. Jacobson, MSFC

Physical Plant IPT
D. Blackwood, GSFC

Integrated Modeling Group
G. Mosier, GSFC

TECHNOLOGY DEVELOPMENT & VALIDATION

D. COULTER, JPL
PROJECT TECHNOLOGIST

Pathfinder Validation Flights
L. Pacini, GSFC

Optics IPT
J. Bilbro, MSFC

Detector IPT
C. McCreight, ARC

DCATT
C. LeBoeuf, GSFC

Ops Technologies
K. Kalinowski, GSFC

Web Based Project Information Management

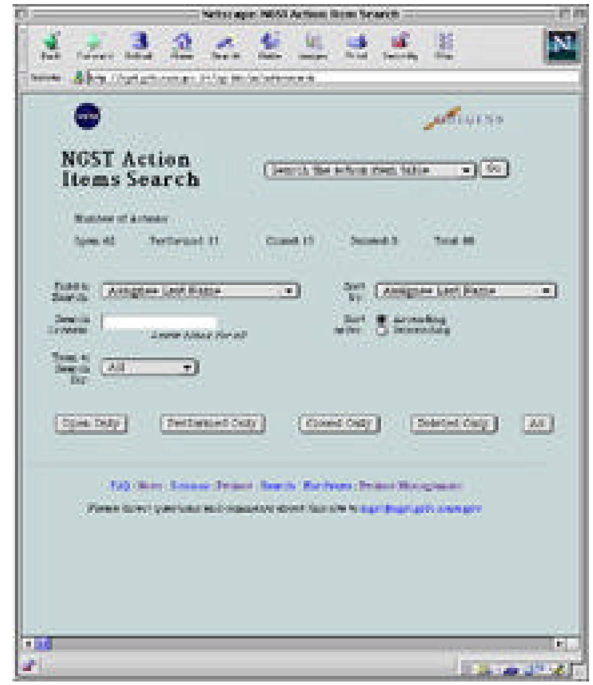
- Philosophy
  - Use WWW to increase and simplify intra-project communication
  - Use WWW to provide starting point for Outreach activities
  - Purchase commercial products if they meet project needs
  - Develop WWW content and software only when it's unique to NGST
- Avenues for intra-project communication
  - Email (many NGST specific `listservs` lists available for subscription)
  - On Technology's MeetingMaker™ for scheduling/short term To-Dos
  - Web pages

http://ngst.gsfc.nasa.gov

Next Generation Space Telescope

Web Based Project Information Management

- listservs (a subset)
  - **ngstweek:** weekly news updates
  - **ngstsci:** Science issues
  - **ngstpress:** Press releases
  - **ngstsysarc:** Systems Engineering news and announcements
  - **ngsttech:** Technology Development IPT news and announcements
  - **ngstprocure:** procurements news and announcements
- Project Administration
  - Action Item Tracking
  - Document Configuration and Control
    - All electronic “documents” accepted and tracked (ASCII, MS Word, electronic images, etc.)
- Exploring intra-project discussion-group server possibilities



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Next Generation Space Telescope

Budget

[backup--from BDS]

Top-Level Schedule

1. Project Phases
A. Mission Analysis & Design (pre-A, A, B) 1 Jan 96 thru 31 Mar 03
B. System Development (C/D) 1 Apr 03 thru 31 Dec 06
C. Launch Processing 1 Jan 07 thru 30 Apr 07
D. Deployment & Commissioning 1 May 07 thru 31 Jul 07
E. Science Ops 1 Aug 07 thru 31 Jul 17

2. Major Project Reviews
A. PMC 27 Feb 99
B. PNAR 1 Jul 00
C. NAR/PDR 1 Aug 02
D. CDR 1 Oct 03
E. TRR 1 Jan 06
F. PSR 15 Dec 06
G. LRR 15 Apr 07
H. SORR 15 Jul 07

3. Major Project Milestones
A. Begin Project 1 Jan 96
B. ISIS Pathfinder Launch 1 Jul 00
C. Single Prime Selection 1 Oct 00
D. Nexus Pathfinder Launch 1 Jul 03
E. Technology Readiness/Approval 1 Sep 03
F. System Construction & Testing Complete 31 Dec 06
G. Launch 1 May 07
H. Normal Ops Commissioning 1 Aug 07
I. DRM complete 31 Jan 10
J. Minimum Lifetime Achieved 31 Jul 12
K. Goal Lifetime Achieved 31 Jul 17

Notional Development Schedule

[see Dan Blackwood's Fastrack charts]

NGST

Summary

Bernard D. Seery

NGST Project Formulation Manager

Where Are We On NGST - A Programmatic Perspective

- We have convinced ourselves that we can meet our Pre-A objectives and move ahead to the next phase of study on schedule
  - ie., PMC Review a year from now
- Based on current NASA guidelines for Study Requirements, we are already well into a Phase A Study
  - this will pay dividends later on when the realities of the mirror fabrication and Pathfinder 3 schedules manifest themselves
  - this will be taken into account as we replan the project to comply with the new 7120.5Project Mgt. Guide
- The current level of studies indicate that it is technically feasible to design and build an NGST of the type we have discussed
  - something at or exceeding the floor requirements can be done within the cost cap

Where Are We On NGST - A Programmatic Perspective

- The big questions to be addressed in 1998 are:
  - what levels of project reserves (contingency) are required for C/D?
  - what do the stretch goals cost?
  - what are the schedules for mirror fabrication as a function of the technology and methodology for fabrication?
  - what processes need to be re-engineered to ensure success?
  - will supplemental technology development funds from our DoD partners fill in the $11M funding gap in 1999?
  - what should we ask for in the next architecture competition and what should be the discriminators?
  - how do we treat the scientific instrument module in light of the interest shown by our international partners?
  - can NGST be tested as a system on the ground, and if so, how?

Where Are We On NGST - A Programmatic Perspective

- NASA Requirements for a Traditional Phase A Study
  - Ł – Estimate of Resources Required for the Mission Life Cycle
  - Ł – Identification of Key Technologies and Estimate of TRL
  - Ł – Technology Roadmap and Implementation Plan
  - Ł – Pre-A study report
  - – Elements & Interfaces Identified
  - Ł – Project Plan
  - Ł – clearly stated science and mission objectives
  - Ł – alternative architectures identified
  - Ł – risk identification and mitigation plan
  - Ł – estimate of produceability and operations
  - Ł – Preliminary Mission Requirements Document

Summary

- ***Positives***
  - **Budget visibility to 2007**
  - **Solid, focused technology development plan**
  - **Good, first order understanding of the observatory**
  - **Multiple mirror technology and methodology pathways**
  - **High caliber government/industry/academe team**
  - **Well understood and articulated science goals and objectives**
- ***Negatives***
  - **Budget shortfalls in 1999/02**
  - **Lack of manpower to support ISIM in house study**
  - **Estimates of cost of stretch options soft**
  - **Single Phase B forces early architecture selection**
  - **Lack of adequate systems engineering on industry teams**
  - **Project inability to identify Stretch IPT lead**